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# NEW HANDBOOK OF THE HEAVENS

*(With Minor Abridgments)*

by

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A MENTOR BOOK

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## Preface

I have enjoyed knowing the stars. We are among the thousands who have found them old friends, to which we can turn after time for refreshing thoughts and relief from the cares and troubles of every-day life.

We have written this book so that others might share this relationship with us. It has been prepared as simply as possible, and it tells of things that anyone can see and understand at himself merely by looking up at the heavens.

But we have found that a great many people, having once looked up, want to lead wings to their explorations by using old-planes or telescopes. To most such "home astronomers" such instruments have a limited use, and so we have included a few telescope suggestions that may be of help to our readers as they grow more ambitious, and to advanced students as well. We have also included carefully prepared lists of the best celestial objects valuable for observation.

We hope that our efforts, meant both to be read at leisure and actual observations in the field, may reveal to you not only a new world—but an unsuspected universe!

HUBERT J. BERGMAN  
DOROTHY A. BINGGOTT  
BOOK S. RICE



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# 1 Introduction to the Heavens

It is fun to know the stars. When night gathers overhead thousands of them appear. There are bright stars and faint ones, near some and far. Some seem scattered at random over the sky while others seem mingled in patterns.

And there are exciting events that are always occurring among them. Once in a while a new star appears, and if you know the old ones you can always pick the new one out. There are the changing phases of the moon and the moon's shifting place along the zodiac. Then there is the possibility that one of those wandering objects, the comets, may appear. If you know the stars, you can easily pick out the visitors from space. And one night, as you are watching the sky, brilliant shooting stars will flash through the heavens. You can add a really important bit of information to astronomy if you know how to watch them and keep records of them.

With even a box camera you can make a permanent record of some celestial events. The rotating earth will shift your camera beneath the stars, and across the photographic plate these distant ones will trail bright arcs. The moon as it drops behind the trees will leave a gradually dimming trail as its light passes through more and more atmosphere and is therefore absorbed.

When you have made your first step into observing the sky you can then go farther. Build a telescope and you can explore the depths of the universe. Double stars and clusters, variable stars and nebulae—all lie within your reach.

Most intriguing of all is the fact that the sky is so full of fascinating things that there is more than a lifetime's entertainment there. In one night one can find many of the star groups, perhaps observe several of the planets, identify dozens of features on the moon, and with the telescope spot numerous double stars, clusters, and nebulae. The next night the same sky will hang overhead but there are thousands of double stars, hundreds of variable stars, innumerable markings on the moon, and countless wealth of still undiscovered wonders within reach of the telescope. The next season a whole new realm of the heavens will be there to explore.



of course, everywhere  $90^\circ$  from both poles just as it is earth. The earth and sky can be considered two great boxes, one within the other. It is  $360^\circ$  around any circle such as the earth's equator for instance. The half-circle from the north pole to the south pole is  $180^\circ$  and the quarter-circle from the equator to the pole is  $90^\circ$ . If the pole star is half-way up the sky in the north, then the equator is about half-way up the south. Of course, to most people this doesn't make any difference, but to sailors and surveyors it is important. They mark such points of reference in the heavens as a means of establishing points of reference on the earth.

So excellent an index of one's latitude is the altitude of the pole star that it has guided sailors since earliest time. Even today this and other stars are used by modern aviators in crossing the trackless ocean.

No one has ever walked around the earth with a measuring tape, yet we know that it is about 25,000 miles in circumference. This is possible to compute approximately when you know the distance between two points on the earth on the same meridian of longitude and then can measure the height of the pole star in each place. Thousands of years ago Eratosthenes in Egypt first determined the size of the earth by a similar method. He believed the world to be round and knew consequently that its circumference measured  $360^\circ$  as does any circle. Hearing from a traveler that the sun appeared at a different height when viewed at the same time from two different cities, he measured the difference in height in degrees. Dividing this figure, and comparing it with  $360^\circ$  he knew what part of the earth's total circumference was represented by the distance between the two cities. When he measured that distance he was able by simple multiplication, to estimate correctly that the earth is about 25,000 miles around.

In the same way no one has ever walked through the earth from pole to pole, yet we know that it is about 7900 miles in diameter. It is possible to figure this out again because we know the earth is round like a baseball. We can measure a baseball and then discover how much farther it is around it than through it. If it is 3 inches in diameter it will be roughly 9.4 inches around. There is a definite mathematical relationship between circumference and diameter in any circle, and we can apply the same rule to the earth.

By other mathematical means, it is possible to measure the 93,000,000 miles distance of the earth from the sun. Our world is one of nine planets that move around the sun. The sun is always shining, so one side of each planet is always light. And as the planet rotates upon its axis, an observer on that turning globe sees the sun apparently rise and set.



There is a real satisfaction in knowing which stars to expect in summer what different stars will decorate winter sky which planets shine in the morning sky what others rise in the west after the setting of the sun

Long ago people traced pictures among the stars. They carved these heavenly figures on stones in Babylon, drew them on papyrus in Egypt fixed them on marble in Greece and painted them on buffalo skins in the American west. These ancient constellation figures can still be recognized, for the stars seem to stay the same in relation to their neighbors for a lifetime and even a thousand years. Really they are drifting in space, but they are so far away that their motion cannot be noticed in a lifetime. To the unaided eye they seem fixed and permanent in position.

Even though they do seem fixed in relation to one another all the stars appear to move together around the earth. Long ago people thought they actually did circle the earth

24 hours the way the sun seems to do. But then it was discovered that the earth itself was turning on its axis and that the apparent motions of the sun and stars were the result of this movement of the earth.

There is one star though that does not seem to change much. It is the brightest in the Little Dipper. Its proper name is Alpha ( $\alpha$ ) its family name, Ursa Minor hence the star is called Alpha Ursae Minoris and is nicknamed pole star. Hanging over the north pole of the earth, over one end of the axis on which the earth turns, it is the brightest star close to the north celestial pole. All the stars seem to rotate around the north star which itself makes a small circle around the celestial pole every 24 hours because it is really 13° away from the true pole. To the casual observer it appears to be quite motionless and always to occupy the same place (for any one latitude in the northern hemisphere (where pole star meant the north star))

However Polaris, the north star has a different position for every latitude within that hemisphere. In the New England states it is about half way up the northern sky whereas at the north pole it is overhead. At the equator however the pole star is just at the horizon. So if you travel to the north the pole star climbs higher the farther you go. When you sail south the star drops lower and disappears if you cross the equator into the southern hemisphere. There the south polar region of the sky comes into view and in the same fashion these stars climb higher above the southern horizon. One travels from the equator toward the south pole

Just as there is a pole of the sky over the earth's pole so there is a celestial equator that hangs over the terrestrial one

of course, everywhere  $90^\circ$  from both poles just as it is on earth. The earth and sky can be considered two great circles, one within the other. It is  $360^\circ$  around any circle such as the earth's equator. For instance, The half-circle from the north pole to the south pole is  $180^\circ$  and the quarter-circle from the equator to the pole is  $90^\circ$ . If the pole star is half-way up the sky to the north, then the equator is about half-way up the south. Of course, to most people this doesn't make any difference, but to sailors and surveyors it is important. They use such marks of reference in the heavens as a means of establishing points of reference on the earth.

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By other mathematical means, it is possible to measure the 3,000,000 miles distance of the earth from the sun. Our world is one of many planets that move around the sun. The sun is always shining, so one side of each planet is always lit. And as the planet rotates upon its axis, an observer on that turning globe sees the sun apparently rise and set.

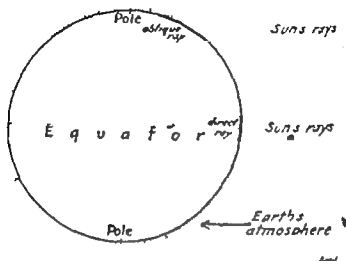


Figure 1 Insolation.

Insolation depends upon the inclination of the sun's rays, and the absorption of the atmosphere when we consider equal areas, a constant output of solar energy and equal distances from the sun. The diagram shows these two effects, closely connected with the change of seasons. In high latitudes, a bundle of solar rays is spread over a large area and thus is less concentrated than a similar bundle of rays at lower latitudes. Similarly it is evident that oblique rays pass through a greater thickness of atmosphere consequently losing much of the lighting and heating power.

In considering the motions of the earth it is convenient to assume that the sun's position is a constant one. Since the earth does not move in a perfect circle around the sun it is sometimes nearer and sometimes farther from it. In January we are about 3 000 000 miles closer to the sun than in July. The varying distance does not make winter and summer however. The actual shift of the season comes from quite different causes. The earth is round, wrapped about with a blanket of air and tipped upon its axis. Sunlight must penetrate the air before it can warm the earth beneath it. Vertical rays of sunlight which strike directly down upon the plane are the most effective as the accompanying diagram shows because they pass through a minimum amount of air and fall upon a comparatively small surface area thus concentrating their heat. The slanting rays, on the other hand, pass through a much greater thickness of

lod, and in doing so lose much of their heat to the air. Then, hitting the surface on a slant, the rays are spread over a larger area than the vertical ones.

Now if the axis of the earth were straight up and down (perpendicular) to the plane in which the earth moves, vertical rays would always strike at the equator and slanting rays at higher latitudes. But the earth is tipped (its axis is inclined  $23\frac{1}{2}^\circ$ ) away from the perpendicular to the orbit in which it moves about the sun. As the world moves round the sun with its axis always tipped at the same angle and pointing in the same direction, first one pole and then the other is nearer the sun. The direct rays shift from  $23\frac{1}{2}^\circ$  north of the equator to the same distance south of that imaginary line. The sun shines alternately  $23\frac{1}{2}^\circ$  beyond the north and then beyond the south pole. The days grow long in the northern hemisphere and then become short. These are the underlying causes for the change of the seasons.

As the seasons come and go, one can see the changes in the sun's position that bring the seasons about. During some winters, the sun is higher in the heavens at noon than during others. And, too, it seems to shift its place constantly against the background of stars as the earth moves around it. The sun's light is so scattered through the air that the sky is too light for us to see the stars, but they are always there. On rare occasions, solar eclipse makes it dark enough in the daytime for us to see them. We discover that the stars close to the sun in summer are the very ones that we see in the far skies of winter. Of course, if the eclipse occurs in winter, we see stars near the sun that we saw on the nights of summer. There is a particular section of the sky that the sun and moon always occupy. The ancients recognized it and divided it into constellations, all but one of which represented some animal. It is called the zodiac, or band of animals, and along it with the sun seems to move.

As the earth revolves around the sun it makes the sun seem to have an apparent motion among the stars—really a reflection of the earth's true movement. Although we cannot observe it quite as easily as the daily rising and setting of the sun, we can detect it as the ancients did. They noticed that each evening after the sun set down, certain stars of the zodiac could be recognized above the western horizon. As the nights passed, the same stars set earlier and seemed to go to meet the sun. The stars that were above the western horizon at the beginning of the month would set with the sun at the end of the month. Thus the sun seemed to progress westward to east along the center of the zodiac.

As the earth moves in its elliptical path around the sun, the moon

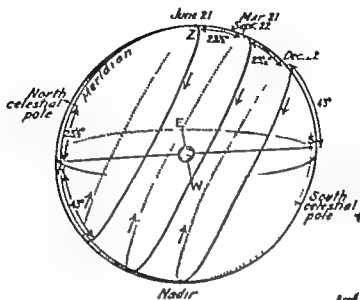


Figure 2 THE SEASONS

At different seasons of the year the noon sun appears at different altitudes to an observer at any one station. Our diagram is drawn for a locality in latitude  $23\frac{1}{2}^{\circ}$  N. Most important cause of the change of seasons, as illustrated in this diagram is the difference in length of day and night at different times of the year for the length of the sun's path above the horizon indicates the daylight hours.

The sun moves regularly among these same stars, as do the planets at various intervals. The moon's path, always close to the sun's, crosses it in two places. Where the orbits cross, eclipses occasionally occur. Either the moon comes between us and the sun and hides the latter or the moon enters the earth's shadow and is darkened. Because of the eclipses that occur here the sun's path was named the ecliptic.

But the earth is tipped upon its axis, and as a result of this the celestial equator is inclined to the ecliptic and crosses it. Where equator and ecliptic cross are the equinoxes—points along the sun's apparent path reached near March 21 and September 23 each year. From these points in the apparent path the sun's rays strike the equator directly and all over the earth there is equal day and night.

After the equinox times, the situation changes. Climbs

of the equator after March 21 the sun's vertical rays lie between north of the equator. On June 21 or 22, the sun is at its most northern point. Then it takes the northern half of the earth longer to turn through sunlight than through night. The northern nights are short, days are long. This is due to the solstice—summer for the north but winter for the south. Each day after late June the sun goes south. It crosses the equator September 23. Fall begins, and day and night are equal again as the sun's most direct rays fall at the equator. After this the sun continues to go farther south and December 21 or 22 it has dropped to the Tropic of Capricorn. The warm rays and the long days have gone south with the sun. The short and cold days of winter are in the northern hemisphere and the sun is very low in the northern sky.

As the sun changes its noon-time or meridian position, it also changes its place of rising and setting. At equinox time the sun rises exactly east and sets exactly west. On those days the sun is on the celestial equator. As the earth rotates on its axis, the sun rises in the east and seems to move across the sky on the equator setting in the west. As the sun climbs north of the celestial equator it rises to the north of the east point, and sets to the north of the west point, reaching its most northern position in each case about June 21. Then as it begins to move back to the equator it again rises due east in September but by December when it is far south of the celestial equator it rises to the south of the east point and similarly sets to the south of west.

Long ago the ancient peoples learned to tell the exact time of the seasons by watching the shift of the sun's place of rising and setting. Early monuments in China, Japan, Central America, and the American southwest were oriented to make observations of these changes possible. Even the Stonehenge in England was used for this purpose.

And of course as the earth turns on its axis each day the sun rises at different times for different longitudes. This makes it strange in time that was not even thought of in the oldest days before people could keep track of what was happening on the other side of the world. But now that radio connects the whole of our planet instantaneously it is possible to be sure exactly what time it is in China as well as in New York. In fact it is possible actually to tell your longitude from the time—because the two are closely related. When the sun is in London it is still dark in New York; on the other hand, it is already afternoon in Shanghai. People on the east coast of the United States must wait 3 hours for the sun to appear above their eastern horizon after it has come up in England. And in the same fashion, people in San Francisco must wait 3

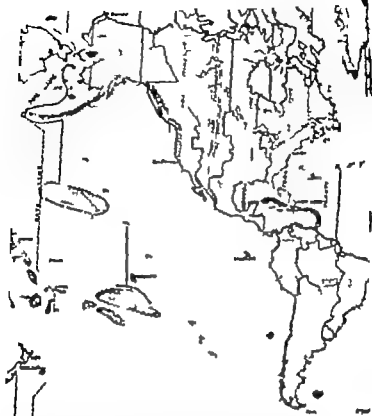


Figure 3 Time-Zones

The earth is divided into 24 standard time zones, each 15° wide longitude. This section of a U. S. Coast and Geodetic Survey chart shows only the western hemisphere. The time in all stations of one zone normally differs by a full hour from that in adjoining zone and zones vary in outline according to the convenience of local within. Diagonally shaded regions indicate the few areas where zone and time does not differ by one whole hour from adjoining zone.

hours to see the sun after it has come up in New York. On this was merely interesting, but now it is used to help locate the positions of ships at sea and the big clipper airplanes fly the ocean.

All that is necessary to determine difference in longitude to know the time of any two places on the earth and from this you can tell the east-west distance between them. The usual method is in use Greenwich time as a standard for

ch to measure, and then figure local time from the altitude of the sun or other astronomical data and the tables in an ephemeris or nautical almanac. The time difference is directly convertible into longitude distance between the observer and Greenwich meridian. You can use stars instead of the sun and they are really preferable. So modern ships and airplanes all carry a clock that shows Greenwich civil time, and this is used to check the clocks. This is now called by the name of Universal time, because it is used the world over for the establishment of longitude and for many other scientific purposes. Stations located  $15^\circ$  of longitude to the west of the Greenwich meridian have local time reading one hour earlier than Greenwich time; stations  $75^\circ$  to the west, or in the East Standard time-zone, have their local clocks 5 hours earlier than Greenwich time. So it is around the world. One can tell time by the sun wherever he is on the earth. Comparing it with the Universal time he can establish his position east or west of the prime meridian. One of the most important things that time does then is to help fix positions on the earth, and so it is possible to tell latitude from the pole star or the sun, and longitude from the sun or the stars.

Star-gazing is like a magic carpet that can carry you away from the earth, and remove you far from the cares of every day. You need only to put your head out the window to start upon this trip of exploration into the outer reaches of space, where one can sense the immenseness of the universe and the remarkable law and order that prevail in it.





Figure 3 Time-Zones

The earth is divided into 24 standard-time zones, each 15 longitude. This section of U. S. Coast and Geodetic Survey map shows only the western hemisphere. The time in all stations of one zone normally differs by a full hour from that in adjoining zone and zones vary in outline according to the convenience of travel within. Diagonally shaded regions indicate the few areas where time does not differ by one whole hour from adjoining

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All that is necessary to determine difference in longitude is to know the time of any two places on the earth and from this you can tell the east-west distance between them. The usual method is to use Greenwich time as a standard for

drawn. After reaching the south pole we would find that the star south of the celestial equator had become circumpolar. For each latitude there is a different group of circumpolar stars.

You can easily discover what stars are circumpolar for your sky by measuring the altitude of the pole star or looking your latitude in the almanac. Any star that is no farther from the pole star than the pole star is from the horizon will be circumpolar. Like this circumpolar area which is always visible, there is from the same latitude an equal section in the other hemisphere always invisible. As you go from equator to pole the circumpolar area increases. As you go from pole to equator it decreases.

Since the greater part of the population of the United States and of many parts of Europe lies in the middle latitudes, most people are familiar with the stars that are circumpolar for the middle latitudes of the northern hemisphere. Among these the Big Dipper (or Great Bear) the Little Dipper, Cassiopeia, Perseus, and others are well known.

The Big Dipper properly known as Ursa Major is composed of seven bright stars. Four stars form the bowl, three the handle of the Dipper. The same three stars that we see in the handle were employed by the Greeks and Romans to make the tail of the Great Bear. The four we use to make a bowl they used in picturing the bear's hind quarters. Despite the different pictures that have been made with these seven stars, their arrangement has always been much the same. The Egyptians described them as a hippopotamus; yet they use the same arrangement that we find today.

Five of the Dipper's stars seem to be of the same brightness, and two are fainter. All the stars that we can see with the eyes alone have been classified according to their brightness and placed in six arbitrary groups. The 20 at the top of the list are  $2\frac{1}{2}$  times brighter than the greater number of stars in the second-magnitude group. The next type, the third-magnitude stars, are  $2\frac{1}{2}$  times less bright than those of the second-magnitude group. This proportion is used throughout the scale.

Some 9000 stars can be seen with the unaided eye all over the earth throughout the year but only some 500 to 1000 at any one time in any one place. They range from the sixth magnitude to the first, and the first-magnitude stars are 100 times as bright as the faintest stars that we can see.

There are a few stars brighter than first magnitude. These stars which in these middle northern latitudes are shown as they appear at any time in a clearly unobscured position from the "Star Explorer" have not yet been observed. I took them from the *Journal Astronomical Club*, Rutherford, New York, 1884-85.

## 2 Stars around the Poles

WHEREVER ONE lives upon the earth there are certain stars that he can see night after night. At the north pole of the earth, for instance, one always sees the same stars—they never set and are visible at all hours every night. As the earth turns on its axis each 24 hours the whole sky seems to circle with every star at a definite and constant height above the horizon. Those near the horizon seem to move parallel to it, and those overhead circle in a direction opposite to the hands of a clock. Every star seen from the pole is circumpolar. In these are in only half the sky the other half never rises at the north pole and is forever invisible from that point.

Suppose, though, that you were to leave the north pole and go as far south as Minneapolis. This city and all others at the same latitude are exactly half way between the equator and the poles. The pole star therefore hangs half way down the sky instead of at the zenith where it was seen from the north geographical pole. In Minneapolis all the stars in view on any night still seem to move around the pole star, but a few of them rising out of the east and climbing above the southern horizon will sink from view in the west and be out of sight for some time during the night. Above the northern horizon there are certain stars that continually swing around the north celestial pole and never disappear. Since they are in view for every hour of every night they are among the easiest to find and identify. They are the key stars of constellation study—the circumpolar stars. They form an easy guide to other stars near by groups.

If our journey be extended and we continue to the equator we find the pole star at the horizon and no stars circumpolar for all of them both rise and set. Our pole star Polaris, lies on the northern horizon and off at the southern horizon the south celestial pole is located. Continuing our journey to the south we would find the south polar region on a higher arc. When we reached Tasmania the south celestial pole would be nearly half way up the sky. Again a group of stars would circle the pole remaining in view through the whole of the night. But at this pole they move in the opposite direction.

now. The two in the bowl which correspond to the point of the Great Dipper are considerably brighter than their neighbors. Just as the pointers are called by that name, so the spooling stars in the Little Dipper are called the stars. They seem always to swing about the pole star which mentioned these stars in the log of his famous voyage across the ocean and many other navigators have taken them as a guide in measuring the hour of the night and the place upon the sea.

The Dippers are so arranged that when one is upright the other is upside down, and their handles extend in opposite directions. Hanging in between the two Dippers is part of the Dragon. The end of his tail lies almost directly over the pointers and the pole, and the coils of his long body curve out beyond the Little Dipper's bowl, swing back and forth again, and finally turn toward the constellation of Hercules in a reversal.

After you have recognized the Great Dipper, traced the stars to the pole star and found the Little Dipper hanging in Polaris—you might trace a line from the pointers to the pole star and extend it an equal distance on the other side. There you find you close to a V-shaped group, Cassiopeia. Across the pole from Ursa Major and equally distant from Polaris this group that represents, some say a big chair upon which the ancient queen of Ethiopia is seated.

At the course of a night Ursa Major and Cassiopeia circle heaven like the opposite sides of a wheel. At 9 p.m. May the Great Dipper hangs upside down, Cassiopeia resembles a right side up on the opposite side of the pole. As the night runs, Cassiopeia climbs the northeastern sky while the Great Dipper drops down to the northwestern horizon. At the in middle latitudes, their positions are reversed by a very turn. At 9 a.m. they have exactly changed places. But still evening the Great Dipper is again high overhead, and Cassiopeia hangs just above the horizon.

Cassiopeia is a typical constellation. It is a group of stars that to us looks always the same. In fact, it appeared the same more than thousand years ago when it first received its name and even longer ago than that when people first viewed it. Yet some of the stars in this constellation are nearer to us than others, and all of them are separated from each other by millions of miles. From some other corner of the universe these same stars would not form the same picture. This same corner of the universe at some other time their arrangement will be different. For all the stars are really flying through space. The speeds and directions of hundreds of stars are known. They are so distant from the earth that it takes

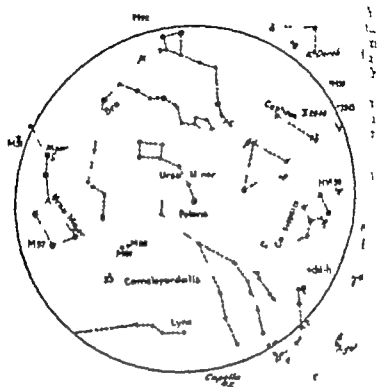


Figure 4 NORTH CIRCUMPOLAR CONSTELLATIONS

are reckoned on the same scale. Stars 1½ times as bright as first magnitude are designated as zero magnitude. Stars brighter than that are labeled minus. Thus Sirius, our brightest star, is magnitude -1.58. The lowest value represents the greatest brilliancy. So Polaris is among the second-magnitude group, and five of the seven stars in the Great Bear are of this same brilliancy. It is no wonder, then, that the Dipper is easy to find at a glance and Polaris easy to locate when one follows the pointers of the Dipper.

The "pointers" are the two stars opposite the handle of the Great Dipper. By following a line drawn from the bottom of the bowl through the pointers and extended about 5 times the distance between them, one comes to the pole star. To make sure that this is Polaris, one should learn Ursa Minor, the Little Dipper, as well. The Little Dipper has Polaris in the end of its handle, the brightest star in the constellation. There are three stars in the handle and four

row. The two in the bowl which correspond to the point the Great Dipper are considerably brighter than their partners. Just as the pointers are called by that name, so the corresponding stars in the Little Dipper are called the *arctics*. They seem always to swing about the pole star. Columbus mentioned these stars in the log of his famous voyage across the ocean and many other navigators have had them useful in measuring the hour of the night and its place upon the sea.

The Dippers are so arranged that when one is upright the other is upside down, and their handles extend in opposite directions. Wading in between the two Dippers is part of *Leo*, the Dragon. The end of his tail lies almost directly between the pointers and the pole, and the coils of his long body curve out beyond the Little Dipper's bowl, swing back toward *Polaris* again, and finally turn toward the constellation of *Heracles* in a reverse "u".

After you have recognized the Great Dipper traced the stars to the pole star and found the Little Dipper hanging in *Polaris*—you might trace a line from the pointers to the pole and extend it an equal distance, on the other side. There you lead you close to a w-shaped group *Camelopardis*. Across this group that represents, some say, a big chair upon which the ancient queen of *Ethiopia* is seated.

At the corner of night *Ursa Major* and *Camelopardis* circle the heavens like the opposite sides of a wheel. At 9 p.m. May the Great Dipper hangs upside down, *Camelopardis* resembles a right side up on the opposite side of the pole. As the year turns, *Camelopardis* circles the northeastern sky while the Great Dipper drops down to the northwestern horizon. At midwinter, in middle latitudes, their positions are reversed by a quarter turn. At 9 a.m. they have exactly changed places. But next evening the Great Dipper is again high overhead, and *Camelopardis* hangs just above the horizon.

*Camelopardis* is a typical constellation. It is a group of stars that to us looks always the same. In fact, it appeared the same more than a thousand years ago when it first received its name and even longer ago than that when people first observed it. Yet some of the stars in this constellation are nearer to us than others, and all of them are separated from one another by millions of miles. From some other corner of the universe these same stars would not form the same picture. The same corner of the universe at some other time their arrangement will be different. For all the stars are really flying through space. The speeds and directions of hundreds of thousands. They are so distant from the earth that it takes

several thousands of years for any change in their arrangement to be noticeable to the naked eye. Nevertheless in our instruments their motion can be detected over a period of years, and we know that a time will come thousands of years in the future when many of the familiar star figures will be hard to recognize.

Some of the star groups are truly related. Five of the bright stars in the Big Dipper for example belong to the same family. The "open cluster" of its members moves as a group through space, all the stars sharing a common speed and direction of motion.

For a lifetime of a man upon the earth, through the passage of many generations during the years of a millennium, the sky will look much the same. So the 89 constellations in which the sky has been divided today will be there tomorrow and will serve as points of reference for men a thousand years from now. Cassiopeia is just one of these 89, yet it is typical of the rest. Its borders include not just the w-shaped figure which is so easy to see with the eye, but many faint stars near that one must look closely to find. Then, too, there are double stars that lie within this constellation area which are only revealed as double in the telescope. Here too are clouds of stars and hazy patches of light that are called the nebulae. Stars that vary in their light can be found in this area also. One night one can learn to find the "w" and to recognize Cassiopeia seated upon her throne. Many nights must pass, though, before one can easily pick out the boundaries of the "star state" and find with his unaided eye all the stars that belong within it. Many more nights may be spent in discovering those hidden objects that lie within the reach of the telescope.

Near Cassiopeia is the section of the sky which the Greeks named after Cassiopeia's son-in-law, Perseus. A straight stream of stars that runs from Cassiopeia to the little group of the Pleiades depicts Perseus. He still holds in his hand the head of the Medusa, relic of his heroic adventure with the Gorgons. One of the wicked eyes of the snake-haired monster still shines but seems to close now and then. For in Perseus is a "blinking star" that changes its light from day to day. Although it is called named by the Arabs the Demon star, another variable star in Perseus is Rho ( $\rho$ ).

Algor is a common name and Rho is a scientific name. If all stars have common names—only the brighter and more spectacular as a rule were named individually—but the astronomers must be able to identify any star in a constellation. The common practice of using Greek letters to designate different stars in the constellation has been followed.

centuries. Then Algol is also Beta ( $\beta$ ) Persei. Usually the brightest star of a group is called Alpha, the next Beta, and so on down the line. Of course, there are many stars that run out of Greek letters they used numbers, Arabic letters, and a system of codes that related the star to its place in astronomical catalogs.

In Perseus there is another object that bears a Greek name. A twin cluster of stars visible to the unaided eye as two very patches, Chi ( $\chi$ ) Persei. Similar objects to these, other Chi stars, and other variable stars lie within Cepheus, Lacerta, and Lynx—all constellations circumpolar for the middle northern latitudes. Most important of these is Cepheus, the bandman of Cassiopeia and the King of Ethiopia. He lies almost in line with the Great Bear but on the other side of the pole star in the Milky Way. So many constellations are figures in Greek mythology that

with the stories adds to one's pleasure in astronomy. You remember how Cassiopeia, Queen of Ethiopia, was beautiful and vain. She aroused the jealousy of the Sea Nymphs and aggravated them into action. They went to Neptune demanding her punishment. Neptune ordered Cassiopeia to take her daughter Andromeda to the seashore and chain her to rock. Then a huge sea monster would have devoured her, but Perseus happened along on his way from slaying the Gorgons. He glided down on his winged horse, Pegasus, cut the Medusa's head out of his pouch, turned the sea monster to stone, and rescued the lovely lady. Then he restored her to her charmed mother Cassiopeia, and her grateful daughter Cepheus. All these are in the same part of the sky as Andromeda, Pegasus, and the sea monster are very

Some persons do not care for mythology; they are more interested in the rich historical and geographic heritage of the stars. They recount the adventures of South Sea Islands sailors who follow the stars for thousands of miles over the trackless sea. Or they point out that the Crow Corvus, is known as the Raven in French, Corvo in Italian, Rabe in German. The Hebrews called it Noah's Ark and to the Chinese a Red Dragon. So the stories of the stars take one over the world and through time.

In Cepheus is one of the most famous of variable stars, Delta ( $\delta$ ) Cephei. By the way, when you use the Greek letter for the star it is customary to use the genitive case of the name of the constellation following. Then it is Delta



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Near Cassiopeia is the section of the sky which the Greeks named after Cassiopeia's son-in-law, Perseus. A jagged stream of stars that runs from Cassiopeia to the little group of the Pleiades depicts Perseus. He still holds in his hands the head of the Medusa, relic of his heroic adventure with the Gorgons. One of the wicked eyes of the snake-haired monster still shines but seems to close now and then. It is in Perseus a "blinking star" which changes its light from day to day. As it is called, named by the Arabs the Demon star. And a variable star in Perseus is Rho ( $\rho$ ).

Aleph is a common name and Rho is a scientific name. All stars have common names—only the brighter and more spectacular as a rule were named individually, but the astronomers must be able to identify any star in a constellation. The common practice of using Greek letters to designate different stars in the constellation has been followed.

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So many constellations are figures in Greek mythology that their stories adds to one's pleasure in astronomy. You remember how Cassiopeia, Queen of Ethiopia, was beautiful and vain. She aroused the jealousy of the Sea Nymphs and aggravated them into action. They went to Neptune demanding her punishment. Neptune ordered Cassiopeia to take her daughter Andromeda to the seashore and chain her to rock. Then a huge sea monster would have devoured her, but Perseus happened along on his way from slaying the Hy Gorgon. He glided down on his winged horse, Pegasus, at the Medusa's head out of his pouch, turned the sea monster to stone, and rescued the lovely lady. Then he restored her Cepheus. All these are in the same part of the sky. Cassiopeia, Cepheus, and Perseus are circumpolar in mid-latitudes. Andromeda, Pegasus, and the sea monster are very close to the horizon.

Some persons do not care for mythology they are more interested in the rich historical and geographic heritage of the stars. They recount the adventures of South Sea Islands sailors who follow the stars for thousands of miles over the trackless seas. Or they point out that the Crow Corvus, is known as the Raven in French, Corvo in Italian, Rabe in German. The Hebrews called it Noah's Raven flying over the deluge. The Arabs call it the Raven Beak and to the Chinese a Red Bird. So the stories of the stars take one over the world and back through time.

In Cepheus is one of the most famous of variable stars, Eta ( $\eta$ ) Cephei. By the way when you use the Greek letter for the star it is customary to use the genitive case of the name of the constellation following. Thus it is Beta

Persel instead of Perseus Delta Cephei and Alpha L Minoris. It is simple after you have once discovered *the system is*. It is really a kind of universal language in which people interested in the stars all over the world can use and understand, an astronomical Esperanto if you will, a kind of sign language that all nations can understand.

Of course people who live south of the equator will choose the Big Dipper as their guide to the night sky—rather the Southern Cross. Wherever you live there are familiar stars that remain in view night after night. These are the ones on which to begin. Then as the seasons roll on your explorations can branch out to include the new visitors of spring and summer and the changing stars of autumn and winter.

### 3 Autumn and Winter Stars

DAYS BEGIN to grow short and leaves fall from the trees. The nights of autumn grow longer and winter arrives. Then a greater number of bright stars appears and the best of meteor showers visit the earth. A knowledge of the constellations is a great help in reporting these shooting stars. On September evenings a brilliant triangle composed of three of the 20 brightest stars in the heavens passes overhead. One of the blue-white sun in Lyra, the Harp is one of these stars. The fourth brightest star in the whole of the sky is Alpha in the constellation of Lyra. It has as its neighbors four very brilliant jewels set in a parallelogram. One is Beta and Gamma form the magnificent Ring nebula, within reach of a small telescope. The second of the three stars in the big triangle is Deneb, the brightest star in the Northern Cross. Although the Cross is easy to recognize, the ancients visualized the same stars as forming a Swan, and the proper name of this sky area is actually Cygnus. The stellar area enclosed within the boundaries of Cygnus houses many interesting objects. There are 61 stars, the first star to have its distance measured Beta Cygni, Deneb, one of the most beautiful of the double stars within reach of a small telescope and the Cockatoo that looks like a real overgrown hole in the sky. The last corner of the triangle is marked by Altair, principal star of Aquila, the Eagle. Altair shines in the Eagle's head and Deneb shines in the tail of the Swan. Thus the Swan flies in one direction down the Milky Way while the Eagle wings its flight in the opposite direction. Easiest thing to do on these nights of fall is to pick out the three bright stars and then the star pictures of which they are a part. After that, there are many other near-by constellations that are easy to identify. There's the tiny group of Delphinus, the Dolphin, below one arm of the Cross and over the head of the Eagle. Only five stars can be seen readily in this little group which some people call Job's Coffin. Even so, one can find here several interesting objects with the telescope. Gamma

is a double star in the Dolphin's head, and behind his tail a hazy patch which in the telescope is a cluster of comets.

Between Delphinus and Albireo at the head of Cygnus is the image of an arrow. The constellation, made of five stars, is labeled Sagitta. Between Sagitta and Cygnus is an even more inconspicuous figure Vulpecula, the Little Fox from Aesop's fables. Prize object in this area is the Dumb-bell Nebula—an oddly shaped telescopic patch of misty light.

Sagitta and Vulpecula require real searching. So save them for the time when you are looking for new fields to conquer and feel an irresistible urge to find something that your fellow star gazers have not yet discovered. Actually of course Cygnus and Aquila, Delphinus and Lyra are remnants of nights of summer. They are crossing the south in the evening in early autumn. As the hours pass they will sink to the west and disappear before the dawn. Driven before them will go the stars that hung in the west in the early evening. There are Boötes, off the curve of the Dipper's handle, and Corona Hercules Ophiuchus, and Sagittarius.

When trying to describe the location of one constellation in relation to another we must have some method that will always work. At first it might seem as though the easiest thing would be to say to your fellow astronomer "When you see Orion, Sirius will be just below and to the left." This may apply when Orion is on the meridian and your friend is in the northern hemisphere. However it would be incorrect 3 hours earlier or 3 hours later on the same evening in the same locality and it would be just the opposite in the southern hemisphere. In the long run, it is not wise to use the terms above, below, right or left, up or down when giving directions in the sky.

It is far better to start out correctly. Imagine the sky as a big sphere overlaid with circles like a spherical birdcage. The hour-circles pass through the poles, but other circles at right angles to these are parallel with the equator and are called *parallels of declination*. There is one hour-circle that is very easy to visualize—the *meridian*. When you face due south you can imagine it running from the horizon through the zenith or overhead point, on to the north celestial pole and down to the horizon. (Out of sight it continues on through the south celestial pole as the *anti-meridian*.) Suppose that Orion seemed to be just over the south point on the meridian. To describe Auriga properly you would say it was north of Orion. It is between the head of Orion and the north celestial pole. However I repeat that the great circle that started at Orion and passed through the head of Orion and the north celestial pole is the meridian.

though Auriga strikes Lepus beyond Orion on his way toward the south celestial pole.

Through the belt of Orion runs the celestial equator. Every line between the equator and the north celestial pole is said to have a declination north. Objects between the equator and the other pole are said to have a declination south. Just as the whole sky is overlain with lines through the poles similar to the meridian, one for any star anywhere, so at right angles to the hour-circles may be imagined other lines parallel to the equator—parallels of declination. Every star everywhere has such a parallel of declination.

All the stars that we can see have long since been carefully noted on the framework of hour-circles and parallels of declination. This framework can be used by an observer any place on earth and any time of day or night.

The declination of an object is measured in degrees north or south from the celestial equator. If the figure has a plus sign before it, you know the object is north; if it has a minus sign before it, you know the object is south. Thus Capella in Auriga has a declination about  $+46^\circ$  while Alpha Leporis has a declination about  $-17^\circ$ .

In describing celestial directions it is safest to use the terms north and south only in this connection, (always in reference to directions on the sphere, not in connection with the cardinal points of the compass as applied to the horizon). From a star's place on its hour-circle its distance north and south of the equator can be described. To tell its place east and west along its parallel of declination we must have a similar point of reference. The vernal equinox is that point—the place where the ecliptic and equator cross and which the sun passes over March 21. The right ascension of a star is measured from the vernal equinox in hours. The distance is measured outward from this equinox to the point where the hour-circle that goes through a star crosses the equator. Obviously the right ascension of a star which is given in hours, is similar to geographic longitude, while the declination of a star is similar to geographic latitude and is given in degrees.

Each star has a permanent place on the celestial sphere, where it can always be found. For instance, Betelgeuse (Alpha in Orion) is located near right ascension  $5^h$  declination  $+7^\circ$ . However this is more than you need to describe how to find Arion in relation to Betelgeuse. First find the two stars, connect them with an imaginary line and note the line's direction with respect to the hour-circles and parallels of declination. It will be seen that Sirius lies south of Betelgeuse and to the west, on the celestial sphere while Aldebaran lies to the north

is a double star in the Dolphin's head, and behind his tail a hazy patch which in the telescope is a cluster of countless stars.

Between Delphinus and Albireo at the head of Cygnus is the image of an arrow. The constellation, made of five faint stars, is labeled Sagitta. Between Sagitta and Cygnus lies even more inconspicuous figure Vulpecula, the Little Fox from Aesop's fables. Prize object in this area is the Dumbbell Nebula—an oddly shaped telescopic patch of misty light.

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When trying to describe the location of one constellation in relation to another we must have some method that will always work. At first it might seem as though the easiest thing would be to say to your fellow astronomer "When you see Orion, Sirius will be just below and to the left." This may apply when Orion is on the meridian and your friend is in the northern hemisphere. However it would be incorrect 3 hours earlier or 3 hours later on the same evening in the same locality and it would be just the opposite in the southern hemisphere. In the long run, it is not wise to use the terms *above*, *below*, *right* or *left*, *up* or *down* when giving directions in the sky.

It is far better to start out correctly. Imagine the sky a hemisphere overlaid with circles like a spherical birdcage. The *hour-circles* pass through the poles, but other circles at right angles to these are parallel with the equator and are called *parallels of declination*. There is one hour-circle that is very easy to visualize—the *meridian*. When you face due south you can imagine it running from the horizon through the *zenith* or overhead point on to the north celestial pole and down to the horizon. (Out of sight it continues on through the south celestial pole as the *ant meridian*.) Suppose that Orion seemed to be just over the south point on the meridian. To describe Auriga properly you would say that it was *north* of Orion. It is between the head of Orion and the north celestial pole. However Icarus is *south* of Orion because the great circle that started at the

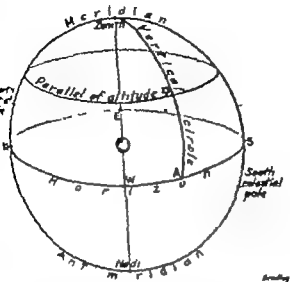


FIGURE 6. OVER MICHIGAN

located objects on the celestial sphere is that employing altitude and azimuth—the coordinates of the horizon system. Altitude is the height of the object above the horizon as measured along the vertical circle,  $A$  to  $*$  where  $*$  represents object. Azimuth is the distance of the object, measured either along the horizon or "parallel of altitude" from the meridian to the object's vertical circle. In astronomy it is measured from south point westward ( $S$  to  $A$ ) but in navigation it is measured from north point eastward ( $N$  through  $E$  and  $S$  to  $A$ ).

and west in the direction of the setting sun. The relationship between these stars will every time and everywhere appear the same and can always safely and accurately be described in this paper.

There is another system for describing the star positions—altitude and azimuth. Since this system depends upon the observer it is variable with time and place. The altitude, of course, is the star's height above the horizon in degrees; the azimuth is the distance in degrees measured westward from the south point of the horizon around the circle to the point where the star's altitude circle meets the horizon. In navigation, however, the zero point of azimuth is at the north point of the horizon. To be able to know these coordinates—especially



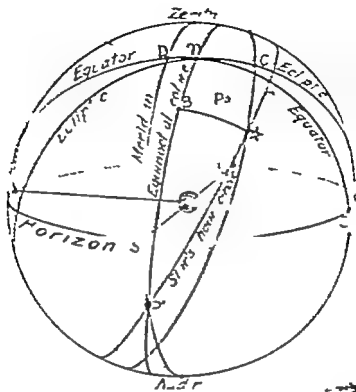
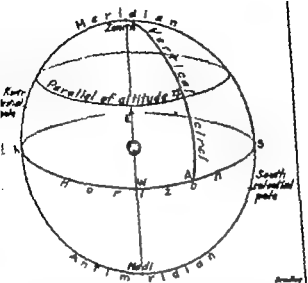


FIGURE 3 THE M &amp; B DISTANCE -

But it is worth studying! The diagram representing the celestial sphere with the earth at the center shows the celestial equator and the ecliptic system. We have chosen as our point (\*) which has the following coordinates as measured along the line of the diagram:

- T—Tropical equator
- E\*—Right ascension
- A\*—Declination
- C—Celestial latitude
- C\*—Celestial longitude
- CTA—Celestial distance of A\* from C
- DWE around the circle: A—Hour angle
- P, P'—Celestial poles
- N, E, S, W—North, east, south, west—celestial positions

Are also D on equator and around the circle: — Celestial



### Figure 4. Case Mechanism

setting objects on the celestial sphere is that employing altitude & azimuth—the coordinates of the horizon system. Altitude is the height of the object above the horizon as measured along the vertical (Fig. A to \* here \* represents object. Azimuth is the distance of an object, measured either along the horizon or "parallel of altitude" from the meridian to the object's vertical circle. In astronomy it is measured from south point outward (S to A) but in navigation it is measured from north point outward (N through E and S to A).

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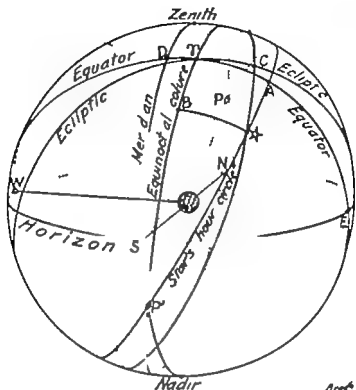


FIGURE 5 THIS MAY BE DIFFICULT

But it's worth studying! The diagram representing the celestial sphere with the earth at the center shows the coordinates of the equator system, and of the ecliptic system. We have chosen an object (\*) which has the following coordinates as measured along the lines of the diagram

T—Vernal equinox

B\*—Right ascension

A\*—Declination

TC—Celestial longitude

C\*—Celestial latitude

CTA—Obliquity of ecliptic

DIVE around the circle to A—Hour-angle

P, P—Celestial poles

N, E, S, W—North, east, south, west—cardinal points

Arc from D on equator westward  
around the circle to T—Sideral

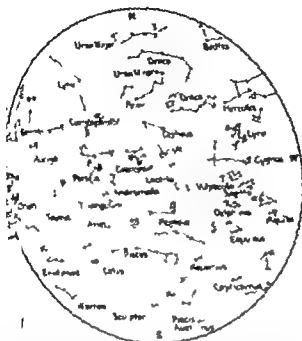


Figure 1 Chart of Autumn and Winter Stars

This chart shows the accepted geometrical patterns of all the constellations visible at 9 p.m. November 6 in latitude 45° N. Chief stars listed for study in the chapters on "Double and Multiple Stars" and "Variable Stars" are indicated, as are the first-magnitude stars, which are the following:

Orion—Betelgeuse	Taurus—Aldebaran	Virgo—Spica
Ursa Major—Dubhe	Lyra—Vega	Polaris—North Star
Draco—Rathorn	Cygnus—Deneb	Auriga—Capella

Unrecorded, the sun's place was in Aries on the first day of spring. Since then, Aries has been called the first sign of the zodiac, even though precession of the earth's axis has slowly moved a shift in the place of the sun at the time when spring begins.

In modern times, the sun is seen against the background of the Fishes when it crosses the equator about March 21, the vernal equinox, a reference point

for navigation—but for most astronomical purposes the ascension-declination system is more in use.

Off in the east of the sky early on the nights of autumn Pegasus, Andromeda, Triangulum, Aries, Pisces, and Aquarius—properly the stars of fall. Most characteristic of all these groups is the great square of Pegasus. To the ancients he represented the white winged horse that inspired the poets of and carried Perseus through the sky after he had slain Medusa. To a modern boy however this section of the sky looks like a baseball diamond. There are the home plate, first, second and third base, even the right and left field foul-line and the catcher.

In the old story Perseus was riding upon Pegasus when he looked down upon the shores of Ethiopia and there he saw Andromeda chained to the rock. Appropriately then, the constellation of Andromeda lies very near to Pegasus. In fact they share one star in common, Alpheratz, frequently mentioned by Anne Morrow Lindbergh in *Listen the Wind*. Andromeda was the daughter of Cassiopeia and Cepheus and finally the wife of Perseus. Since they are all close together in the heavens, it is easy to find them and to remember them.

The corner stars in the square of Pegasus are so bright that the area inside the square looks quite like empty sky. On a clear night, though a person with good eyesight can see well over half a hundred stars inside the square. With a telescope he can see many more. Some of these are double stars and some are grouped in clusters.

When you are searching the square of Pegasus for the nebula that you can recognize, look along Andromeda for a faint patch often called Messier 31. When you have finally located this milky patch just barely visible to the eye, it is hard to believe that it is actually made of 100,000,000,000 stars like the one that we see each day. It is so distant that only a telescope and camera combined can show its true nature. They reveal it to be a whole universe of stars like the Milky Way galaxy of which we are a part. While you have your telescope there be sure to turn it toward Gamma Andromedae for this star is a beautiful double that can be easily separated with a small telescope.

Once familiar with Pegasus and the long line of Andromeda, you will have no difficulty in recognizing the V-shaped group of Pisces in the south, as well as the two smaller constellations, Triangulum and Aries, in this same region. The Triangle lies just south of Gamma Andromedae and Aries hangs an equal distance south of Triangulum. The star Gamma in Aries is also a double easy to resolve. Much more important however is the fact that long ago the zodiac was

of the belt toward the northwest of Orion and you come  
 10 Aldebaran in Taurus. Thence along the belt toward the  
 20 head of the Hunter and you encounter the brightest star  
 30 in the sky Sirius, the Dog Star. Although the Greeks and  
 40 Romans identified this brightest star with the Dog, the  
 50 Egyptians interpreted it as the beak of a bird. Watching for  
 60 Sirius when Sirius rose just before the sun, the Egyptians  
 70 measured the length of the year and devised a fairly successful  
 80 calendar.

90 Sirius is one of the nearest stars. Although some 50 trillion  
 100 miles separate it from the earth, it is very near compared with  
 110 other stars. That helps to explain its brightness (its magnitude  
 120 is -1.54) and also makes clear why the Dog Star is one of  
 130 number of stars that seem to have shifted in relation to  
 140 their neighbor stars since people first made record of the sky.  
 150 Hipparchus discovered that in his time Sirius and Vega both  
 160 failed to appear in slightly different relation to their neigh-  
 170 bors than they did to the Egyptians. Prompted by this dis-  
 180 crepancy he made careful study and finally noticed the shift of  
 190 the reference point, the vernal equinox, too. He decided that  
 200 the place of the sun on the first day of spring was creeping  
 210 slowly westward along the zodiac with the centuries. That he  
 220 credited with the discovery of the procession of the equi-  
 230 nox. Now we know that, as 26,000 years pass, the earth  
 240 makes once upon its axis like a spinning top. This motion  
 250 makes the position of the celestial pole and consequently that  
 260 of the equinox shift continuously against the background of  
 270 stars. As a result, different stars become pole stars; and the  
 280 position occupied by the sun on March 21 as it crosses the  
 290 equator in the vernal equinox, slowly shifts along the ecliptic  
 300 with the centuries.

310 Although procession makes the stars' places appear to  
 320 change in relation to points of reference in the sky, it does not  
 330 alter their relationship to one another. However, the actual  
 340 positions of the stars themselves will change the stars' places  
 350 in the course of time. Many thousands of years are required  
 360 before most of the stars change noticeably their apparent  
 370 places, but for Sirius the change is more easily observed  
 380 because it is so great.

390 Compared to the Big Dog, Canis Major with its brilliant  
 400 first-magnitude star, is the Little Dog, Canis Minor with  
 410 its bright star Procyon. Between the two Dogs a group of  
 420 four stars represents Monoceros, the Unicorn. Monoceros  
 430 proper is like Vulpes, the Fox, and Sagitta—a real test  
 440 of the navigator's seeing ability.

450 Just as there are two Dogs so are there two boys, Castor  
 460 and Pollux. The Twins belong in the zodiacal constellation

from which the positions of all celestial objects are reckoned.

Along the zodiac beyond Aries and Pisces lies Aquarius, the Water Carrier, and past him towards the west, Capricorn, the Goat. Capricornus follows after Sagittarius, the Archer, and it disappears beneath the western horizon on autumn evenings.

South of the zodiac is Cetus, the Whale. In this constellation area a variable star shines, named by Hevelius, Mira, the Wonderful. A strange "blinking" star Mira takes about two months to change from second magnitude to sixth and finally vanishes from naked-eye sight, reaching tenth magnitude nearly a year. Its variation changes it from a star as bright as Polaris to one invisible to the unaided eye.

As Cetus comes out of the southeast early on autumn evenings, Taurus, the Bull, rises in the east and follows after zodiacal neighbor Aries. Taurus has many claims to fame. the time of the Egyptians it was the most important of the groups along the path of the sun for the vernal equinox was located there at the time. The Bull's Eye, Aldebaran, is one of the 20 brightest stars. In the Bull's face is a little cluster of brilliant stars, the Hyades. On the Bull's shoulder is the famous group of the Pleiades, often called the Seven Sisters, sometimes the Seven Brothers. Although it has long been called the Seven Sisters, there are only six stars that can be seen at glance, whereas at least 250 can be recognized in the cluster with a telescope. Sometimes November is called the Pleiades month because this group is so prominent in the eastern sky in the early evening.

Most spectacular group of the winter season is Orion, the Hunter. Two first-magnitude stars, Betelgeuse and Rigel, decorate this constellation area and several of the second brightest are included within its boundaries. Three bright stars equally spaced in a straight row form the belt of the Hunter; the three more represent the sword, and five are prominent in the figure of the man. Betelgeuse in the right shoulder, Bellatrix in the left, Rigel in the left foot and Saiph in the right are easy to recognize. Two of the stars of the belt are fine doubles, and in the sword is a magnificent nebula, the star in the right shoulder is one of the largest known, and Rigel has about the greatest intrinsic brightness of any star.

Since the belt of Orion shows the location of the celestial equator, Orion's head and shoulders belong to the northern hemisphere, and his legs and feet lie south of the celestial equator. Since all diurnal motion of the sky through the hours of the night takes place parallel to the celestial equator, it is well to know the location of Orion's belt. It can also guide you to the eye of the Bull and the nose of Big Dog. Tri-

as we look toward the northwest of Orion and you come  
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Since the belt of Orion shows the location of the celestial equator Orion's head and shoulders belong to the northern hemisphere, and his legs and feet lie south of the celestial equator. Since all diurnal motion of the sky through 24 hours of the night takes place parallel to the celestial equator it is well to know the location of Orion's belt. It can be seen to the eye of the Bull and the

## 4 Spring and Summer Skies

THE LION, is one of the 12 zodiacal constellations and is the most ancient of star groups. Its sickle-shaped head and triangular tail are easy to identify as it crosses high over northern horizon early in the evenings of April and May. The easy way to locate it is to find the Great Dipper in the sky and follow the pointer stars in the opposite direction to the pole star. Down through the bottom of the Dipper 1, an imaginary line will lead right to the head of the Lion and on to the brilliant star Regulus in his heart.

It is said that this group received its name because the sun is in Leo when the early Egyptians watched for the solstices of the Nile. At this season the lions came down the Nile, so a likeness of a lion was pictured in the stars. The finest star in the group, Regulus, is one of the nearest neighbors of the sun, but it is less than one-tenth as bright as our star. It is the faintest of the first-magnitude stars. Because it is one of the 20 brightest stars, is prominent in the zodiac, and is especially close to the ecliptic, it has been carefully plotted and constantly watched for centuries.

Hipparchus, in comparing the stars of his day with charts of his hundreds of years before his time, discovered that certain other stars appeared to have changed their places. Not the stars, but the framework of reference based upon them, had shifted. Thus westward precession has carried the autumnal equinox along the ecliptic to a spot in eastern Virgo just south of the Lion's tail. Leo possesses a blue second-magnitude star Denebola, or Beta, at the tail, and one of the sky's finest doubles, Gamma, at the neck. The yellow-and-green stars of which it is composed can be seen with 3-inch telescopes. A larger glass than 4 is necessary to give proper separation to the triple components of Alpha, for although Regulus itself is first magnitude, its companions are eighth and thirteenth magnitude.

Gamma in Virgo is also a double with an eighth-magnitude partner—one easily visible in a 3-inch glass. The same scope will find a rich field of clusters and nebulae between Virgo and Leo.

Gemini one of the 12 star groups along the ecliptic. Castor and Pollux are much closer together than Sirius and Procyon since about 4° separates the first pair but four times the distance separates the latter.

Of course, this is just the way they appear on the celestial sphere when seen from the earth. From some other place their arrangement would seem different. Actually millions upon millions of miles lie between the Twins, and one nearly twice as far from us as the other. Describing the relation to each other in degrees is just like drawing the places on a map. One point upon the map may represent a mountain 18,000 feet high while another point upon that paper may represent an ocean depth many miles below a level. So a map of the sky represents the stars as we see them and gives no indication of the fact that some may lie 10,000 times as far away as others.

Gemini could be called the "Times Square" of the sky. Like the cross-roads of the world it entertains all kinds of visitors. On its way around the zodiac, each month, the moon passes through its boundaries. Once each year at the summer solstice the sun passes near Eta Geminorum, and summer begins in the northern hemisphere. Shooting stars each year in December seem to radiate from Gemini. Close beside Beta in 1781 Sir William Herschel discovered a new world, the planet Uranus. Beside Delta Geminorum, in 1930 Clyde Tombaugh finally identified a tiny speck upon the photograph plate as the ninth planet in the sun's family—Pluto. Double stars, variable stars, clusters, nebulae can all be located within the boundaries of this constellation area.

No wonder then, that the nights of winter in the northern hemisphere offer great reward to the star-gazer. The brightest stars, the most spectacular constellations, the longest nights—all these serve to make the cold season ideal for observation of the stars.



Figure 8. Change of the Service Sector

map shows shows the accepted geometrical patterns of all the positions visible at 10 March 6, to latitude 40° N. Chief stars in the study is the chapters on "Double and Multiple Stars" and "Bright Stars" are indicated, as are the first-magnitude stars, which are the following:

1. ~~Wife~~—Capella      ~~Daughters~~—Castor      2. ~~Orlando~~—Migd  
 2. ~~Wives~~—Raphae      3. ~~Daughters~~—Pallas      3. ~~Castle~~—Majors—Borne  
 3. ~~Wife~~—Abdeltus      4. ~~Orlando~~—Belshazzar      4. ~~Castle~~—Majors—Piercy

The best known naked group of the summer months. With brilliant red star Antares, and its long curving tail, the Orion is easy to recognize. Antares is a giant sun 400 times diameter of our own and tremendously distant from us. It is well known to the ancients, and modern astronomers have found that it has very green companions. Antares is partially hidden by the moon and, when such an occultation occurs, is a startling sight to observe with the telescope.

of the telescopic objects there that he called the region "realm of the nebulae"

The only first magnitude star in Virgo is Spica. A blue sun of great brilliance. Spica is so far away that it requires 192 years to travel across the space that separates it from the earth. Since light travels 186,000 miles a second, a trillion miles a year, it is obvious that Spica must be brighter than the sun but unbelievably farther away. It has a tiny invisible companion which was discovered while analyzing its spectrum with a spectroscope.

Cancer the Crab is the next zodiacal group west of Leo. During the month in which the sun appears to pass through this section of the zodiacal band, the Crab is, of course, invisible. It is inconspicuous most of the year as only a few faint stars compose the figure. A misty patch in the center of the constellation is called Praesepe. It is a cluster of thousands of stars so distant that only on a clear night can they be seen with the naked eye. Only with a telescope can they be separated, even at the edge of the group.

Between Cancer and the horizon can be found a small pentagon of stars that picture the head of Hydra, the serpent. The most extensive constellation of the whole sky, Hydra winds beneath Cancer, Leo, Virgo and Libra. At about 120° one-third the way around the heavens, the sparkling serpent stretches. Yet over its whole length it has but one bright star, a second-magnitude one in its heart. Called the Heart of Hydra, it is properly called Alpha Hydrae. Another name is Alphard.

Several small constellations are arranged along the back of the serpent. Close to Alphard, in fact lying directly between Alphard and Regulus, rests Sextans. A little farther to the east Crater the Cup balances on the serpent's back. South of Denebola in the Lion's tail. Still farther toward the tail, close to Virgo, perches Corvus, the Crow. Corvus, the way it is a convenient little group to know. If you want to locate the Southern Cross, just find Corvus, and Crux is directly south of it. One can always find Corvus by starting with the Great Dipper, following the curve of the Dipper's handle south to the bright star Arcturus, continuing on at the same distance to sparkling Spica, and then south again an equal distance to Corvus.

Next group along the zodiac east of Virgo is Libra, the Scales, once represented as a balance of justice. The constellation is almost a square, or diamond, between Scorpius, Virgo, Alpha in Libra is a double star separable with field glasses, while Beta is the only bright green star in the heavens. Far more spectacular than either of its neighbors, Scorpius

er Carrier is the next group along the zodiac. On the  
 as of the Babylonians it was represented as a man with a  
 er jar, although the Arabs imagined it a trade carrying  
 er barrels. There are no bright stars in the whole area and  
 group is not easy to identify. The easiest way to locate it  
 is find Fornax first. First-magnitude star just south of it  
 is the corner of Pegasus just north of it. Then with consid-  
 erable imagination you can trace out the water jar the holder  
 the jar and a stream of water pouring into the mouth of  
 (Southern Fish, Piscis Austrinus).

Most prominent of all the spring groups, Leo can be seen  
 the early evening from March to June. Succeeding it  
 the dominates the early evenings of July and August with  
 is crowns in Hercules close by. Directly south of Corona,  
 begins is the outstanding zodiacal group for the summer  
 season. The appearance of Capricornus above the southern  
 horizon together late night hours of summer or the evening  
 its of the coming fall is observers in the northern hemi-  
 sphere. When Fornax first crowns the south in the early eve-  
 ning, summer is over and high above the great Square of  
 Pegasus warns us of the presence of winter and the approach  
 winter. When once more the winter stars rise out of the  
 it is early evening the spring and summer groups have run  
 its course and drift out of sight in the west after each night.  
 So as the seasons roll the patterns of the stars are a constant  
 reminder of the journey of the earth round the sun, as repre-  
 sented by the apparent circuit of the sun around the zodiac-  
 tal circle and its changing, thin endless wheeling of the sky is  
 hence of the never the progress of time. Year after year  
 every other century the world pursues its tireless course,  
 is the heavens bear more evidence to its motion. Few things  
 we are that are as dependable as the shift of the stars with  
 seasons, the rising of the sun, the passing of the days.  
 Each constellation group that effects these heavenly changes  
 but a window frame through which one may look to the  
 by borders of space. Bright stars comparatively close to the  
 its compose the outline, but off in the distance are others  
 its brighter but not so our eyes because of the vast space  
 food. is the constellation outline may be red star or a  
 blue one perhaps fainter or larger or twin star. Some-  
 times passing time hand much nearer the the nearest star  
 nearest may appear for time to belong in the star group  
 is shooting star may seem to fall from that familiar section.  
 its are but passing stars, framed for the moment on that  
 noon of the sky. A planet, too may swing this way and for  
 some weeks one with the other members of the constellation,  
 as it moves on in the confines of its orbit, another con-





ly affected by time. Each of its members a sun moving  
 its space, perhaps alone, perhaps in company with other  
 stars of the family—that sun in time will leave some of  
 neighbors far behind. The familiar figures, slowly shifting  
 through the centuries, will one time dissolve their present  
 ties as their members become absorbed into new patterns.  
 If through all the memory of one man the constellations  
 were constant, then the rock of Gibraltar. They offer a  
 support to time, direction, season. They present a passport  
 toward and mysterious regions of space.



bottom of Alpha Crucis is the well-known Coal-sack nebula which looks like a great black hole in the sky. When Wm. Herschel was the first of these objects on his survey of the southern skies he was much impressed, and it is said that he called his sister to the telescope to see the "hole"—a hole into outer space. It was to be expected that his son, in exploring the southern skies, would label any similar holes by the same name. But modern astronomers disagree with the Herschels and no longer regard these dark spots as holes scattered so generously in the Milky Way as he. Probably they are great dark clouds of dust and gas which absorb the light of stars that must lie beyond them. Sometimes the dark nebula beneath the arm of the Cross is known as the Black Magellanic Cloud.

Two other features of the southern skies bear Magellan's name; they are two hazy patches like detached portions of the Milky Way. There is nothing like them in the northern hemisphere, and Magellan's expedition reported them to northern astronomers among the curiosities seen in the other half of the sky. Since then they have always been called the Greater and the Lesser Magellanic Clouds. Also known as Nebula Major and Nebula Minor they are among the first sights which one searches the southern skies.

The Greater Cloud is about 7° in diameter nearly 14 times as full moon; the Lesser not even 4° in diameter covers an area not as large as Cetus. A full moon occasionally brightens the sky so that it is a little difficult to locate the smaller cloud, and even then the larger one can be found with ease.

Examinations of these two clouds has shown that they are made of all types of celestial objects that exist in our Milky Way. There are bright stars and faint ones, red stars and blue ones, large ones and small ones, variable stars, star clusters, bright nebulae, dark nebulae—a complete array. The Clouds of Magellan are island universes and close neighbors of the Milky Way galaxy which is our home. The small cloud is about 14,000 light-years distant, the large one about 75,000 light-years. When one recalls that light travels 186,000 miles per second and traverses 6 trillion miles in a year then these hazy families of stars seem far away. Photography brings out a haze of stars around them, and their distance apart is about 30,000 light-years.

The Magellanic Clouds are irregular in shape and present a ragged appearance that contrasts sharply with the great spiral in Andromeda and other island universes. Some 3000 variable stars have been recognized in the clouds, among them which enable astronomers to measure their distance. The large Cloud is rich in super-giant stars, and 30 globular

## 5 Stars of the Southern Sky

Most of the ancient observers of the sky lived in the northern hemisphere, so south of the equator the heavens reversed. The constellation of Orion depicts a man standing on his head the familiar Scorpion waves his tail in the air and even the Big Dog balances on his nose. Of course inversion of the constellations does not occur all at once they shift slowly overhead as one travels on the surface of earth.

Suppose a traveler leaves New York City for the south. As he journeys toward Florida the stars in the south rise higher those in the north drop closer to that horizon. If it were evening in May he would have his first glimpse of the Southern Cross off the tip of Florida. By the time he reaches Havana he would find it well in view. If he should go to the equator he would see the cross one-third of the way up the sky and at Lake Titicaca, Peru, half way from horizon to zenith. His journey on through the southern hemisphere would carry it higher and higher.

This same Southern Cross is a guide to the south celestial pole. Like the Great Bear in the north, it indicates the location of the pole and therefore is often employed by navigators seeking to establish their place upon the earth. In May and June it can be found early in the evening above the southern horizon clearly outlined by four stars of almost equal brilliance. Alpha is at the foot of the figure nearest the south pole. Gamma is at the top. Beta and Delta in the arms. Gamma is a reddish star bright to the eye but faint on the blue-sensitive photographic plate. Kappa is also a reddish star and is that appears fainter on the photographic plate than in the sky. Surrounding Kappa, though, are over 100 stars in a cluster.

From top to bottom this Southern Cross, Crux, measures 6°—no taller than the distance between the pointers of the Dipper. It covers, in fact, an area about one half that of the bowl of the Dipper—about  $\frac{1}{10}$  of the sky. But while within the Dipper's bowl only nine stars are visible there are within the boundaries of the small constellation Crux 32 stars within reach of the naked eye.

Southeast of Alpha Crucis is the well-known Coal-sack hole which looks like a great black hole in the sky. When William Herschel saw the first of these objects on his survey of the northern skies he was much impressed, and it is said that he called his sister to the telescope to see the "hole"—a hole into outer space. It was to be expected that his son, when exploring the southern skies, would label any similar dark lanes by the same name. But modern astronomers disagree with the Herschels and no longer regard these dark ones that are scattered so generously in the Milky Way as holes. Probably they are great dark clouds of dust and gas that absorb the light of stars that must lie beyond them. Somewhere the dark nebula beneath the arm of the Cross is known as the Black Magellanic Cloud.

Two other features of the southern skies bear Magellan's name; they are two hazy patches like detached portions of the Milky Way. There is nothing like them in the northern heavens, and Magellan's expedition reported them to northern astronomers among the curiosities seen in the other half of the world. Since then they have always been called the Greater and the Lesser Magellanic Clouds. Also known as Nube de Major and Nube de Minor they are among the first sights met with one searches the southern skies.

The Greater Cloud is about 7 in diameter nearly 14 times as full moon, the Lesser not even 4 in diameter covers an area not as large as Crux. A full moon occasionally brightens dark sky so that it is a little difficult to locate the smaller cloud, it even then the large one can be found with ease.

Examination of these two clouds has shown that they are made up of all types of celestial objects that exist in our Milky Way. There are bright stars and faint ones, red stars and blue stars, large ones and small ones, variable stars, star clusters, numerous nebulæ, dark nebulae—a complete array. The Clouds of Magellan are island universes and close neighbors of the Milky Way galaxy which is our home. The small cloud is about 24,000 light-years distant, the large one about 75,000 light-years. When one recalls that light travels 186,000 miles a second and traverses 6 trillion miles in a year then these amazing families of stars seem far away. Photography brings out a host of stars around them, and their distance apart is about 30,000 light-years.

The Magellanic Clouds are irregular in shape and present a straggling appearance that contrasts sharply with the great spiral and in Andromeda and other island universes. Some 3000 variable stars have been recognized in the clouds, among them are those which enable astronomers to measure their distance. Large Cloud is rich in super-giant stars, and 30 globular

clusters have been recognized there. In the Greater Cloud S Doradus, a super-giant variable, 500,000 times as bright as the sun. Some 180 000 000 miles in diameter it is, except some super-novae, intrinsically the brightest object known. There too, surrounding S Doradus, is the Great Loop Nebula the largest known gaseous nebula in the universe.

After you have found the Southern Cross and picked the Clouds of Magellan the next objects to attract attention are Alpha and Beta Centauri. First and second brightest stars in Centaurus, they are often called Guardians of the Cross. If you draw an imaginary line through Delta and Beta Centauri (along the cross-bar of Crux) it guides you to these two stars in Centaurus. The constellation, which represents a figure half-man and half horse is one of the largest in the southern sky. It is nearly 45° in length almost half the distance from the horizon to the zenith.

A particularly interesting and magnificent star is Alpha Centauri. Not only is Alpha Centauri the third brightest star in the heavens, but it is our nearest binary system. The components of Alpha (A and B) occupy 80 years for a revolution around each other. More than this Alpha happens to be a multiple star composed of the binary and a third, its companion (C). The latter Proxima Centauri, is visible to the telescope—with magnitude about 10.5—and is the next neighbor to the sun being about 4½ light years away though Proxima is over 2° away from Alpha and its companion B yet it is connected gravitationally with the latter system and is moving through space nearly parallel to it actually on an enormous curve around Alpha with a period probably over 300,000 years.

Another object in Centaurus for which the amateur astronomer always looks is Omega (ω) Centauri a hazy patch of light that is the brightest of the globular clusters. The cluster is northwest of Alpha Centauri and is a fine sight with field-glasses and even more beautiful with the telescope. It is composed of some 50,000 stars more than 100 of which are variable. Brightest of these is of the 10th or so globe clusters known though one some 6,000 light years distant from the earth.

After a casual glance at the constellation in the south, one is struck with a difference in the constellation figures and names. Although there are some old familiar subjects like Ara, the Altar, Columba, the Dove, Musca, the Fly, Phoenix, the Peacock, Volans, the Flying Fish and Crux Australis, the Southern Cross—there are many more modern figures. One finds a Clock or Horologium, a Compass, a Furnace, Fornax, an Easel, Pictor a Telescope, etc.





often confused with the real Cross, it is frequently of False Cross. A line from the top of this figure to the and prolonged five times that distance does not lead south celestial pole but off toward the Great Circle. A navigator would find himself far from his port if he should steer by the wrong cross.

Northwest of Crux lies Vela, but east of Crux Centaurus is Circinus, the Compass. Alpha Circini is of the Compass, while Beta and Gamma are the top. Not far away one can recognize Triangulum Australe, Southern Triangle. This is a counterpart to Triangulum in the northern hemisphere just as Corona Australis is a real duplicate of the Northern Crown. The Southern Cross is near the tail of the Scorpion and not far from Antares and Norma the Level. All these small constellations are composed of second- and third-magnitude stars.

There is one extremely long constellation in the southern hemisphere, Eridanus, the River. It begins near Rigel in Orion very close to the celestial equator, traces its winding way from Orion to Cetus, past Fornax to Phoenix, and ends in Hydrus. The first magnitude star Achernar at the southern end of the River lies about 15° from the Small Magellanic Cloud and the northern end of this "Mississippi of the sky" is near the great nebula in Orion. Omicron Eridani is a beautiful triple star well worth examining with a telescope. This same constellation is located an extraordinary fine magnitude star. If one traces the course of Eridanus through nine constellations along its boundaries: Hydrus to Cetus, Orion, Lepus, Caelum, and Horologium to the east, then to the north and Cetus, Fornax, and Phoenix to the west.

The Toucan houses the Lesser Magellanic Cloud and globular cluster 47 Tucanae. Some 10,000 stars in the cloud blend together to appear as a single star of fourth magnitude. Hydrus encircles the other border of the Lesser Magellanic Cloud. Between Hydrus and Dorado, the Swordfish, is the Greater Magellanic Cloud and the tiny constellation Reticulum. Between Dorado and Carina can be found Volans, Mensa, the Table Mountain, and Chamaeleon. Musca, the Fly, lies between the south celestial pole and Crux while Apus is south of Triangulum.

East of the Scorpion's tail Corona Australis, Telescopium, Ara and Pavo the Peacock are not far from the south celestial pole. South of Capricornus, the Goat, and Aquarius the Water Carrier lie Pictus Australis, Indus, and Grus, nearer to the south pole than Cetus can be found.

# CHART OF THE SOUTHERN SKY



FIGURE 10 CHART OF THE SOUTHERN SKY

This chart shows the accepted geometrical patterns for the constellations within 90° of the south celestial pole. All the stars listed in this chapter are indicated, as well as the first-magnitude stars, with the exception of the following:

Antares— <i>Antares</i>	$\beta$ Centauri
Arcturus— <i>Arcturus</i>	Crux
Castor	$\beta$ Crux

Other names are the official ones in Latin, except *Tucana*, which is in English on the chart.

At the Towhee and Scorpion. Near the Hydra's head is Argus and Puppis, part of the old ship *Argo*. The rest of the ship, *Vela*, and *Carina* are still closer to the south celestial pole. For the star-gazer who spends much of his time in the south, it is interesting to know the relation of southern constellations to groups familiar in the north. For instance, on

often confused with the real Cross, it is frequently called False Cross. A line from the top of this figure to the and prolonged five times that distance does not lead to south celestial pole but off toward the Great Cloud of Magellan. A navigator would find himself far from his destination if he should steer by the wrong cross.

Northwest of Crux lies Vela, but east of Crux by Centaurus is Circinus, the Compass. Alpha Circini is the head of the Compass, while Beta and Gamma are the two points. Not far away one can recognize Triangulum Australe, Southern Triangle. This is a counterpart to Triangulum in northern hemisphere, just as Corona Australis is a southern duplicate of the Northern Crown. The Southern Crown is near the tail of the Scorpion and not far from Ara, the Altar, and Norma, the Level. All these small constellations are composed of second- and third-magnitude stars.

There is one extremely long constellation in the southern hemisphere, Eridanus, the River. It begins near Rigel in Orion very close to the celestial equator, traces its winding course from Orion to Cetus, past Fornax to Phoenix, and on to Hydrus. The first-magnitude star Achernar at the southern end of the River lies about 15° from the Small Magellan Cloud, and the northern end of this Mississippi of the Stars is near the great nebula in Orion. Omicron Eridani is a beautiful triple star well worth examining with a telescope. In this same constellation is located an extraordinary planetary nebula, a great globe of dust and gas surrounding an eleven-magnitude star. If one traces the course of Eridanus he finds nine constellations along its boundaries: Hydrus to the south, Orion, Lepus, Caelum, and Horologium to the east, Taurus to the north, and Cetus, Fornax, and Phoenix to the west.

The Toucan houses the Lesser Magellanic Cloud and a globular cluster 47 Tucanae. Some 10,000 stars in the cloud blend together to appear as a single star of fourth magnitude. Hydrus encircles the other border of the Lesser Cloud of Magellan. Between Hydrus and Dorado, the Swordfish, is the Greater Magellanic Cloud and the tiny constellation Reticulum. Between Dorado and Carina can be found Puppis and Volans. Mensa, the Table Mountain, and Chamaeleon lie nearer to the south celestial pole than Dorado or Carina. Musca, the Fly, lies between the south celestial pole and Crux, while Apus is south of Triangulum.

East of the Scorpion's tail Corona Australis, Telescopium, Ara, and Pavonis the Peacock are not far from the south celestial pole. South of Capricornus, the Goat, and Aquarius, the Water Carrier, lie Piscis Austrinus, Indus, and Grus, which are nearer to the south pole than Cetus.



Figure 10. Chart of the Southern Sky

This map shows the accepted geometrical patterns for the constellations of the southern celestial pole. All the stars listed in this chapter are indicated, as well as the first-magnitude stars, which are

Antares—Corvus  
Mikar—Antares  
Nunki

Antares  
Corvus  
Mikar

Other names are the local ones in Latin, except Tuxia, which is English in the chart.

of the Tuxia and Sculptor. Near the Hydra's head are the stars and Pyra, part of the old star Argo. The rest of the stars, Vela, and Carina are still closer to the south celestial pole. For the star-painter who spends much of his time in the sky, it is interesting to know the relation of southern constellations to groups familiar in the north. For instance, on

the same hour-circle to the south of Arles lie Fornax, Eridani, Horologium and Hydrus. In order too from Taurus to south celestial pole, are Caelum, Dorado and part of Men South of Gemini, bordering right ascension  $6^h40^m$  lie Puppis Canopus in Carina, sections of Pictor Volans, and Men South of Cancer can be discovered Pyxis, Vela, Vela Chamæleon while along the same hour-circle with Leo Antlia, Vela, Carina and Chamæleon.

Beyond Virgo toward the south pole we encounter Centaurus, Crux, Musca and more of Chamæleon. The hour-circle of  $15^h20^m$  through Libra also cuts Lupus, parts Norma Circinus, Triangulum Australe and Apus. On the hour-circle through Scorpius can also be traced Ara, a bit of the Southern Triangle and Apus, while near-by another Sagittarius, then goes south through Corona Australis, Telescopium, and Pavonis. South of Capricornus on  $20^h40^m$  Microscopium, Indus, and a bit of Pavonis while 2 hours farther south of Aquarius, are Pisces Austrinus, Grus Tucana, and some of Indus. A line through Pisces goes south to Sculptor, Phoenix, and Tucana.

In general these meridians have been selected as near central as possible on the zodiacal groups and on the arcs are 2 hours apart.

When one discovers that Crux lies south of Virgo, the Greater Magellanic Cloud is in the same hour-circle as Taurus, and the Lesser Cloud in the same right ascension with Pisces. It is easy to find the other neighboring groups.

Familiar and friendly to the people of the south, the Alpha and Beta Centauri, the Magellanic Clouds, and the rich star fields of the Milky Way are foreign and fascinating to the traveler from the north.

## 6 The Planets

but were rite of them, and they moved about among the  
stars. Men who looked heavenward were quick to call  
in the planets, which meant that they were wanderers.  
They were different from the stars in more ways than one.  
A very old story always saying within the con-  
fines that he liked the wanderers, but they shone with a  
faint light that was somehow different from the twinkling of  
stars. Early astronomers knew very little about them, and  
it was not until Galileo turned his telescope on the skies that  
he began to learn. After that, but very slowly (at the rate of  
approximately one every 100 years) astronomers began add-  
ing to the number of planets so that we now know eight in  
all in the solar system.

They are the sun's children, brothers and sisters of the sun, and all neighbors in the solar system. But they are not close neighbors as judged by earthly standards. If, in ascending a diagram on the ground, we estimate the step to Mercury and make mark little less than 5 inches from it, that mark might represent the position of Mars, the nearest planet to the sun.

At 1.4 inches we would make another mark, for Vesper, and at 1 foot we could indicate the distance of our 2nd pt. There would be 1 1/2 feet from the sea, and then, between 1 and 4 feet, we would make a series of marks to point out the intertidal—the minor places which are discovered there. We should have to pace off a bit more than 1 foot for the sea, though, to get to Vesper's position and 3/4 ft for Sertora and then walk out 19 feet from the sea for the position of Vesper.

and on the same scale, Neptune would be a full 20 feet from the sun and the newly discovered Urago would be 40 ft. The earth, remember was only 1 foot from the sun. If that foot represented an average distance of 93,000,000 for the astronomical unit.

As for size, the earth is large to us with its 7912-mile  
circumference. Yet Jupiter, the largest of the planets, is more than  
three times the diameter of the earth, and the entire planetary

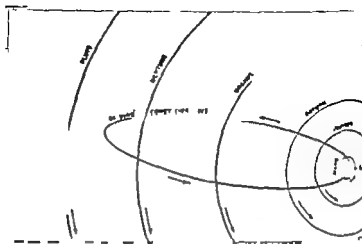


Figure 11 THE SOLAR SYSTEM

A plan view of the orbits of 7 planets. Drawn to scale with one orbit of Di Vico's, included, the diagram gives an accurate impression of relative distances between the planetary orbits. The orbits are shown at mean distances actually in one place Pluto's orbit is nearer sun than Neptune's.

system of Mercury Venus, Earth Mars, Jupiter Saturn Uranus Neptune and Pluto would have to be multiplied hundredfold to make a body as big as the sun.

And there we have roughly a picture of the planetary system as known today although we have not included zodiacal light, comets meteors, and satellites. It is a picture drawn from the outside, of the planets as seen from a point over their orbits, and consequently a picture we can never see from the earth. For the observer here, with only his eyes to help him there are five blazing points of light (and perhaps a sixth dim one, if he knows where to look for it).

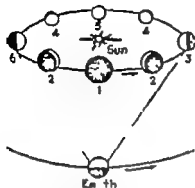
One of these points of light is elusive. That is Mercury which stays close to the sun like a child clinging to its mother's apron strings. Because you must look for it so soon after sunset, or before sunrise, there was a famous astronomer Copernicus, who never saw the planet in all his life. There is also however the story of at least one amateur who has seen Mercury not once but 150 times.

It's all in knowing how. The planet is best seen as an "evening star" in the spring, and as a "morning star" in the fall. But there are six periods in every year when it is fairly well placed for observation, these periods occurring when the





Figure 12. PLANETARY PHASES



Mercury and Venus, the inferior planets, go through similar to those of the moon. The diagram shows

- 1—Inferior conjunction
- 2 and 2 —Greatest brilliancy
- 3—Greatest western elongation (morning star)
- 4 and 4 —Gibbous phase
- 5—Superior conjunction
- 6—Greatest eastern elongation (evening star)

For the planet Venus no exact rotation period, or day yet been satisfactorily determined, because of the impermanent nature of the markings on its cloud surfaces. Recent spectroscopic studies indicate a period of a few weeks. On Venus, however the heat that pours down on the planet is less intense because of two factors—its greater distance from the sun, and its atmosphere which while it holds a great deal of warmth distributes it evenly around the planet.

Venus and the earth might almost be called the twin planets of the solar system. The orbit of Venus, which the planet travels in 225 days, is nearer to a perfect circle than that of any other planet, and that of the earth is not far behind in this respect. The two planets are approximately of the same size Venus having a diameter of 7575 miles and the earth having one of 7918 miles, and they are closer together in their orbits than any other major planets.

Nearness and heavy clouds around Venus account for its appearance of the planet in the sky. For Venus is not most visible. With the exception of the sun and moon she is the brightest object normally seen in the heavens and at her best outshines Sirius, the brightest of the stars by 13 times. Sometimes when there is no moon to interfere she is bright enough to cast a shadow.

And not only is she far more conspicuous than Mercury she is also visible for greater intervals of time. Like the other planet Venus is often out of sight on the other side of the sun but these periods of invisibility are not nearly so frequent as those of Mercury. And unlike the smaller planet Venus can be seen for as much as 4 hours at a time make her appearances in the same way as Mercury. She slides down the celestial vault, trailing the sun in the evening, and when



steaming swamp ■ characterized the earth's early ages; ■ not know. Absence of permanent markings prevents knowing Venus's rotation period. Indications are that ■ is a few earth weeks long.

Mars is an excellent subject for small telescopes. It ■ its famous reddish color to the naked eye (a color ■ persists on its surface when viewed with large instruments and under a small telescope it offers opportunities to ■ details. Even so small an instrument as a 4- or 5-inch ■ will do under the right "seeing" conditions.

Under a telescopic magnification of 200 to 350 diameters grayish or greenish markings stand out against the red background. At less than 300 diameters the polar caps appear and so too does the dark wedge of Syrtis Major extending toward the north. Other dark areas can be picked up as ■ and as telescopic power increases (try it sometime with a to 12 inch reflector) the number of features visible increases.

There are several reasons why we know so much about Martian conditions and surface details. Mars has, of course, long been a subject of great popular interest, but many facts would still be a mystery were it not for the small clarity of the planet's atmosphere. Slight clouds—whether dust or some other composition—appear only infrequently and the Martian air is so transparent as to permit excellent opportunities for study of surface detail.

Then, too, when the planet is in opposition—when the earth and Mars are in a straight line—it comes nearest. 34 000 000 miles, than any other major planet except Venus. At times Mars may be observed going through a slight gibbous phase although it never goes so far as to become a crescent or even as to enter the "half moon" phase.

Mars differs greatly from the earth in size, having a diameter of only 4216 miles. In almost every other point, however, she compares favorably and as a result has become the home for life on one of the planets as conceived by the human mind.

■ this suspicion of life on Mars necessarily reached the world of science, for many reputable astronomers and a majority of them—believe that there is at least some life on the planet. And the existence of vegetation and other conditions which might possibly support some form of life.

■ of life on Mars probably got its start with

Schiaparelli observed strange  
and termed them canals, which

He ■

4 11

a repetition of actuality of something which had been  
announced by intelligible beings.

terrestrial lowland observed great canals and expressed the belief that they were constructed by an advanced race being who dug them to bring water down from the poles. If the character and extent of the canals is debatable, for now there is a question of seeing detail at the extreme limit of visibility. Future telescopes may settle the questions about it more for all time. Although observers now report that J 101 was sections near the canals turn blue-green in one end and dark brown in another.

Memorize these as the known facts that figure in the poems concerning life on Mars.

The atmosphere contains small amounts of oxygen and the vapor both but both values are quantitatively as  $p_1$  in each oxygen and 3 per cent as much water vapor are found in the atmosphere of the earth. The equatorial temperature and  $p_1$  (that) support it as found on the  $p_1$  for a man to  $p_1$  F. The axis of the planet is inclined to the ecliptic at an angle with the sun. The angle is that of the  $p_1$  but combined with a revolution between the orbital planes and conjunction of the two planets would result in highly approximate season. These seasons are twice as long as those of  $p_1$  with because the year consists of 7 days—twice that of the earth. The planet day is half the year of the earth for 1 quarter on the axis to 4 on 37 degrees.

The planet polar caps are in size with the seasons, too, a huge hint is manipulated with color changes to the eyes as seen in Saturn. Super thought by some astronomers to be a sea of ice. The composition of these polar caps can be either frozen carbon dioxide or frozen water. Because color changes occur at the edge of the caps easily melt or solidified to heat that heat then melt they go into liquid and melt it is not carbon dioxide, which will remain frozen through it in the more permanent.

Mars is the 4th planet in the outward journey from the  
A (approx 1st) the 1st has any moons so far  
we know. The 2nd (approx 2nd) has the satellites which  
are discovered. A (approx 3rd) the U.S. Naval Officer, 1877. The  
4th (approx 4th) is the 4th up with any but the  
you let us see whether he is more than 10 miles in diam-  
eter. But Phobos, the inner moon, runs three laps around  
a planet. It is moving and getting three times each 4  
years and moving outward in the same and getting in the same  
4 years it passes the slower Deimos, observers on Mars would

steaming swamp as characterized the earth's early age. We do not know. Absence of permanent markings prevents knowing Venus's rotation period. Indications are that it is a few earth-weeks long.

Mars is an excellent subject for small telescopes. It gives its famous reddish color to the naked eye (a color which persists on its surface when viewed with large instruments) and under a small telescope it offers opportunities to observe details. Even so small an instrument as a 4- or 5-inch telescope will do under the right "seeing" conditions.

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Mars differs greatly from the earth in size, having a diameter of only 4216 miles. In almost every other point, however, she compares favorably and as a result has become the favorite home for life on one of the planets as conceived by the popular mind.

Nor does this suspicion of life on Mars necessarily remain outside the world of science for many reputable astronomers—possibly a majority of them—believe that there is at least plant life on the planet. And the existence of vegetation presupposes conditions which might possibly support some kind of animal life.

The question of life on Mars probably got its start when the Italian astronomer Schiaparelli observed strange markings on the surface and termed them canals, which in language meant channels. He was misinterpreted, though, the lines became known as canals.

act. The satellites often become lost against the background as in transit and may drop out of sight—even in large scopes. The shadow being a black dot, is fairly easy to lose as it glides over the cloud surface of the planet (and may even change its shape at times because the surface is not over so uneven). The satellites in transit require at least a 6-inch telescope, but the shadow thrown on the planet can be seen with a 4-inch instrument at times.

Despite the fact that they seem to move haphazardly appearing, perhaps, all on the same side of the planet one night to scattering around it the next, the four moons of Jupiter seem an orderly miniature of the solar system. Now and then one of them may vanish, and very rarely all four of them may be in front of or behind the planet. Yet each has a definite period (which you may trace for yourself and then set with an ephemeris) each has a definite path and every one of these four travels around the primary in the same direction.

Of the 11 known moons the outermost three revolve in an equatorial or retrograde direction, from east to west. This has led you to determine as to whether they might not be captured asteroids and therefore not originally members of Jupiter's system. The four easily visible in small telescopes are considerably larger and brighter than the others. It is worth noting that Ganymede and Callisto of Jupiter's train, are bigger than the planet Mercury.

There is still another planet in the group that are classed as "dead-eye" objects, and although Jupiter may claim (same as in our system of moons, this other world—Saturn—is a set of rings that is unequalled in the entire universe. It is, our scientific caution prompts us to say the rings are reported so far as we know.

In the spectra of small telescopes, they surprise observers with their beauty even though it be expected. Composed of millions of tiny moonlets, the rings appear as thin, circular panned some 7000 miles above the planet's equator. They are 41,500 miles wide from inner to outer edge, and by comparison with their width they are thinner than loose paper.

This macroscopic character causes the rings to disappear when seen edge-on. At such times they are visible only by the most powerful instruments as thin needles piercing the sky. At other times the rings may seem inclined upward or downward, for they are really inclined at an angle of 7° to the plane of the planet's orbit and lie in the plane of its equator. As Saturn moves around the sun we see them at varying angles—apparently from above, below or edge-on.

see both of the satellites racing each other across the sky with respect to the stars beyond.

Mars, however, is not unique in its set of moons. Jupiter carries with it a retinue of 11 satellites, four of which are easily visible in small telescopes. To look at Jupiter and satellite system we must let our gaze wander far beyond orbit of Mars and over the asteroid zone. The 4½ feet distance between the two in the diagram we planned at the beginning of the chapter (fig. 11) was based on a scale in which each foot represented 93 000 000 miles. Jupiter, despite this great distance, usually seems brighter than the red planet because it is so much bigger and because it reflects nearly three times as much as Mars does of the sunlight it receives.

Jupiter is the largest of the planets and curious astronomers have timed its speed of rotation upon its axis at 9 hours and 55 minutes. As a result of this speed, there is a huge bulge at the equator so great that the diameter of the planet is through the equator 88 698 miles, or nearly 4000 miles more than from pole to pole.

A pair of binoculars or field-glasses shows a tiny disc. Magnification of 18 times will do very well, but is even more than is needed. With a larger instrument, Jupiter resolves into a series of red, yellow, tan, and brown shadings, as well as a wealth of other telescopic detail.

Exceptionally good "seeing" is not necessary to get a clear view of Jupiter's surface markings, and frequently a slight haze or smokiness in the air will help to steady the image. The cloud belts, for which the planet is famous, will appear in low-powered telescopes as parallel bands stretching across the disc. And another feature that the amateur will—or may—be able to observe is the "Great Red Spot" which was identified on drawings made of the surface in 1859 and has disappeared and reappeared during succeeding years. A marking of perhaps similar nature, discovered early in the twentieth century and known as the South Tropical Disturbance may also be observed.

But it is in its moons that Jupiter contains the greatest telescopic treasure for the amateur. The four that are visible in a merry race with each other around the planet and change their respective positions from hour to hour and night to night. They aren't hard to identify with an ephemeris, and they can be followed for hours as they speed in front of Jupiter, throwing their shadows on the planet, vanish behind its giant disc, or plunge suddenly into its deep shadow. Binoculars will locate them if outside the disc.

It is easier to watch one of the moons throw its shadow on Jupiter than to watch the moon itself in front of the





according to the planet's position with respect to the sun. They reflect so much light that when they present their best aspect to the earth Saturn in the sky seems three times brighter than when the rings are edgewise. And when they are edgewise (*which occurs every 15 years*) they are lost in small telescopes nearly so for the very largest.

A medium-sized instrument shows the divisions of the rings clearly. The first one to resolve itself is the dark Cassini division, which divides the system in two and is not hard to detect with a small telescope. On the outer of the two rings thus formed, we may be able to pick up the faint, gray Encke division. And the word "may" is used advisedly for the Encke strip is elusive and not always visible. On the inner ring there is a gradual shading off on the edge next the planet of a shading which melts into the misty gray border of the "crepe" ring. This foggy curtain on the inside of the ring system is comparatively transparent, and the shape of the planet can often be seen through it. The stars, too, because of the tenuous nature of the crepe ring, can be observed and identified through it on occasions.

Saturn throws a shadow across its surrounding belt, a black shape that outlines one rim of the planet and the rings. It in turn throws a soft, neatly bordered band upon the planet. This latter shadow falls upon cloud surfaces similar to those of Jupiter—cloud surfaces that are belted just as those of the larger planet. But few details concerning them can be seen unless unusual observing circumstances prevail. Every now and then a spot—probably related in nature to the Red Spot of Jupiter—appears, but none with the permanence of Jupiter's marking has yet been observed. The most recent one was a white spot which appeared in 1933.

Where Jupiter whirls upon its axis in a bit under 10 hours Saturn requires 10 hours and 14 minutes. But Saturn is more oblate than Jupiter. It has an equatorial bulge of 7900 miles. It is the second largest member of the sun's planetary family with an equatorial diameter of 75,100 miles.

In addition to her rings, Saturn has nine satellites and Jupiter has two larger than Mercury so has Saturn. Appropriately enough it is named Titan. It is nearly as big as the planet Mars. But most of Saturn's moons are unfortunately not easy to observe with small instruments, and but for the observer who could pick up any other than Titan in a 3-inch glass. Were he equipped with a 4-inch telescope however he might be more fortunate. Taking extreme care to distinguish them from the stars, he should be able to identify Titan, Iapetus, Rhea, Tethys, and one (named) of the order of observational possibility.

American Ephemeris for the numerous data necessary to study them.

So far away from the sun is this planet, and so slowly does it pass through the heavens that the earth, after completing all revolutions around the sun, has but to continue for 13 years before we can see Saturn in the same aspect (for example, opposition) as in the year before. If Saturn is far distant, under the cases of Uranus, Neptune, and Pluto—the three planets discovered since invention of the telescope.

The first one was discovered by William Herschel in 1781, or less by accident. The astronomer was making a systematic survey of the stars when he noticed one that seemed to remain in its place. That was the planet Uranus, which is about 31,000 miles in diameter and stays on an average of 11,000,000 miles away from the sun. It can be picked up as a naked-eye object by people gifted with good eyesight, and a certain knowledge of where to look for it. At such a time it appears as a sixth-magnitude object.

A 9- to 12-inch telescope, magnifying from 400 to 500 powers, is needed before Uranus shows any appreciable disk, and then it appears as a tiny green object with faint blue bands. No permanent markings have been discovered on the surface, but characteristic cloud bands can always be traced with the largest instruments.

The planet has five satellites, all very faint and beyond the reach of any but the largest telescopes. And so astronomers, for most part, must be content with locating the planet and giving its path among the stars.

So, too, must we be with Neptune, though here the task of finding the object is more sport. The planet was discovered in 1846 by Adams and Leverrier working independently on astronomical calculations, and its orbit is just about 1,000,000,000 miles farther out than Uranus. It can be seen with a 6-inch telescope and magnifying power of 15 diameters, though its 30,000 miles of diameter does not become a disk till we use a telescope of 9 to 12 inches aperture.

At its brightest it is of the eighth magnitude, and the telescope shows a faint greenish color. Its two satellites are quite fit to reach for amateurs, but Neptune offers one consolation to the telescopist—once located it can easily be followed for the rest of the season because it spends nearly 14 years in each section of the zodiac. The positions found in the ephemeris are plotted on a star atlas, and the corresponding object in the sky that moves daily is the planet and not a star.

If Neptune and Uranus have retired far from the earth, Pluto will make them seem near. For this little world, which is the earth's diameter is now the outermost planet 45

Retrograde Motion of Mars



Figure 13 MARS IN RETR

When the planets are in position Mars appears to be moving normally as seen from the earth. Actually however the earth and Mars and the red planet move more slowly. As a result position 2 it apparently starts to move backward, assuming a retrograde motion. It continues in position 6, where the relative positions of the two planets has changed again. It once more resumes its normal forward motion.

far as known. It takes 248 years for a single trip around the sun and twice in each revolution, it crosses the orbit plane of Neptune.

Its orbit, most eccentric in the system is farther from the sun than that of any of the other major planets. Pluto was discovered in 1930 as the result of years of search begun by Percival Lowell and finished by workers in the Flagstaff Observatory he had founded for planetary research. At the time it was in the constellation of Gemini, but it has since moved over into adjacent Cancer where it will be when you read this (unless you are a bit late) for it remains about 30 years within the borders of each star group. Needless to say it is completely beyond the range of small telescopes and even taxes the power of a 15-inch refractor.

The giant planets (Jupiter Saturn Uranus Neptune) are similar to each other but differ widely from the earth Venus and Mars. Their atmospheres consist of great layers of poisonous gases, ammonia and methane. Below this is an immense thickness of hydrogen underneath which is a thin layer of miles of ice and at the center the dense rocky core. The ammonia is in minute crystals and the methane gaseous. The cold is inconceivable surface temperatures are about  $-200^{\circ}\text{F}$  on Jupiter to  $-300^{\circ}\text{F}$  on Neptune. Conditions of any kind of life on these dark cold distant and forbidding worlds would appear impossible.

There is a naked-eye observation which, if made accidentally and without beforehand knowledge of what is happening, is likely to send any amateur scurrying to the library for an explanation. It may be made for any one of the planets including Mercury and Venus which are visible when they present this phenomenon, and it consists quite simply

an apparent reversal of direction by the object under observation. Hence it is called *retrograde motion*.

A planet, Mars for instance, will be seen moving in its supposed path west to east among the stars, then gradually slowing down, and finally moving east to west, nearly back the direction from which it had been coming. After a short while, it will resume its old motion again. The explanation, which is clarified in the diagram on page 62, (fig. 13) lies in the relative motions of the planet under observation and the earth. The earth has a greater orbital speed than the outer planets, and as it overtakes and passes one of them, that planet seems at first to move more slowly than actually it is moving backward. A similar effect results when passing in one automobile past another on the road going in the opposite direction. As the earth swings further along, in its orbit, the other planet seems to resume its former motion. In the case of Mars and Jupiter apparently describe a retrograde loop like for Saturn, Uranus, Neptune, and Pluto, the loop is much flatter, and they seem to backtrack along their own

Retrograde Motion of Mars

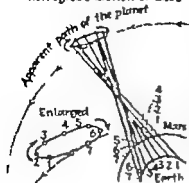


Figure 13 Mars in Retrograde

When the planets are in position 1 Mars appears to be moving normally as seen from the earth. Usually however the earth and Mars and the red planet seem to move more slowly. As a result, in position 2 it apparently starts to move backward, assuming a retrograde motion. It continues in position 6, where the relative motions of the two planets had changed again, it once more resumes its normal forward motion.

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The giant planets (Jupiter, Saturn, Uranus, Neptune) are similar to each other but differ widely from the earth, Venus, and Mars. Their atmospheres consist of great layers of poisonous gases, ammonia, and methane. Below this is an immense thickness of hydrogen, underneath which is a thin layer of miles of ice, and at the center the dense rocky core. The ammonia is in minute crystals and the methane gaseous. The cold is inconceivable: surface temperatures are about  $-200^{\circ}\text{F}$  on Jupiter to  $-300^{\circ}\text{F}$  on Neptune. Conditions for any kind of life on these dark, cold, distant, and forbidding worlds would appear impossible.

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## 7 The Moon

THE MOON is one of the most fascinating of celestial bodies and almost invariably the object of keenest interest viewed by the telescope-user. On account of nearness and size we see the moon with the naked eye and with small optical power can observe a wealth of detail on the surface. It can be observed successfully with various types of telescopes and cameras, and it is often said we know the topography of its surface better than we know some parts of the earth.

The phases of the moon are so obvious a phenomenon that they are noticed by anyone seeing the moon at any time. The cause of phases is easy to understand. The moon is a nearly spherical body and is half-lighted by the sun. As it circles the earth, varying amounts of the lighted half face the earth. Except at full-moon time, only a part of the illuminated spheroid is visible to terrestrials—hence the effect of phases.

At times of new moon, the moon is between us and the sun, and at an eclipse of the sun, exactly so, with the moon's disk silhouetted against the sun. At any other new moon, that producing a solar eclipse, the moon passes by the sun either north or south of the latter and the sunlight falls on the side of the moon away from the earth, hence the moon is invisible for this reason as well as being obscured by the blinding glare of the sun. In a day or two after new moon, we see a narrow crescent in the west after sunset, for the moon is now back-lighted by the sun, just as a tennis ball back-lighted by a source of light shows the same crescent—but we know the rest of the ball is there, even if not illuminated.

During the lunar month the moon travels clockwise in the celestial sphere. Beginning with new moon, it takes position successively more and more such that the direction of a line from the moon to the earth, and a line from the moon to the sun assume a right angle. This is the first quarter, one-fourth of the entire spheroid being visible (or half of the disk) it is then in quadrature with the sun, 90° away from it in longitude. Soon more than half of the disk is seen—the "first half" phase—until finally at full moon, all the half turns

ward as is lighted up. Then the longitude of the moon is from the sun, putting the moon directly on the opposite side of the earth from the sun; this is also called opposition, which time the moon rises at sunset time. After full moon, phases are repeated in reverse order: the disc becomes waning, then at last-quarter phase, and shortly before new moon a thin crescent can be seen over the eastern horizon late morning. The age of the moon is the time elapsed since the last new moon. The age of the full moon is about 14 days. "Crescent after new" is obviously to be found east of the sun, whether seen faintly in the daylight sky before sunset, or as a more brilliant object after sundown; whereas "crescent before new" is found in the sky west of the sun, in the eastern sky before sunrise.

The terminator is a word meaning the variable line between the illuminated portion at any moment, and the part in shadow. Because as the moon is a spheroid, the terminator is actually a complete circle around the moon, corresponding to the circle of illumination on the earth, but the part on the opposite side of the moon is always invisible to us. Generally speaking, if you were at the terminator any time between new and full moon, you would be having sunrise on the moon, exactly as if you were on that section (which is seen from the earth) between full moon and new; you would be experiencing sunset.

The moon is of some real value to the people of this planet. Illuminating the landscape at night, for instance, it benefits in all latitudes, the effect increasing as we go poleward. In very high latitudes the moon at certain times illuminates an otherwise dark sky during the "long polar night" when the sun does not rise at all for weeks. Again, the revolution of the moon gives us a basis for the measure of the month. Of greatest importance of any of the lunar effects are tides, and the moon is mostly responsible for these.

Tides are a phenomenon of regular rise and fall of the sea level, commonly twice a day. While the earth rotates, the ocean passes underneath the moon whose gravitative attraction radically raises the water level. Shipping would notice the effect at once if the moon were annihilated, for vessels would be unable to enter or leave many harbors, so that commercial and passenger trade would suffer untold losses.

Our moon lends itself particularly well to telescopic study because of its nearness to the earth and lack of atmosphere. Nothing on the moon prevents all the features of its surface from standing out clearly and being sharply defined in our telescopes and photographs. To be sure, we are unfortunates in always having but one face of our satellite open to



observation yet that face presents a superb array of graphic features to delight the eye.

One who has not looked much at the moon with a telescope has no idea of the magnificent views to be encountered. Even an experienced observer of lunar landscapes repeatedly finds something new—that is, landscapes under new lights or conditions.

Aside from the purely astronomical sights, there are phenomena observable when the moon is near the horizon that are caused by refraction effects of the earth's atmosphere and the origin of which has nothing to do with the moon. Under certain conditions, various refraction effects distort the moon's image into almost unbelievable shapes. The commonest effect is for the otherwise circular disc to become flattened; it is almost pumpkin-like. Nor does distortion stop here: occasionally the edges become serrated or saw-like; the disc even assumes a step-like appearance—an effect almost indescribable. The bays or indentations "march" along the moon's disc moving perceptibly even during brief observation, and often end with a part of the disc being separated entirely from the rest. Such effects are the result of varying density of a thick ocean of air on the earth's surface, with concomitant changes in refraction low over the horizon.

Any and all magnifications may be used on the moon. Even an opera glass will show the large gray plains, and a field-glass, some of the smaller features. But with high-power binoculars, magnifying 10 to 20 diameters, hundreds of objects can be identified, although they are still small. The smallest object that we have been able to distinguish with 18 $\times$  binoculars is the mountain-ringed plain Lalande (10 miles in diameter) which means that hundreds of objects on the lunar surface are visible with low magnification.

But to do justice to our satellite, we should use a telescope. A 3- or 4-inch refractor opens up a vast field, while reflectors of 6 inches aperture and above will reveal marvelous detail. Low powers are needed when we wish to include the entire disc for general examination. For more detailed work put a higher magnification—60 to 100 diameters are very satisfactory for examination of mountain ranges, chains of crater-like formations, and topographic details of intermediate size. While powers of 200 to 600 linear diameters are used for close-ups and details of the moon's smaller features, such as craters, peaks, and rills.

On the moon, all living organisms needing air for breath would find it utterly impossible to exist for even a few minutes unless they were equipped with special oxygen or air tanks. As far as we can detect, the moon's atmosphere is

existent. We can prove by observation the absence of spheres. There is no ring of light visible around the moon like of a total eclipse of the sun. There are no clouds or areas of darkness visible. The satellite's limb stands out as sharply in the center of the disc, which would not be so if an atmosphere existed. Occultations of stars by the moon show instantaneous disappearance or reappearance of the stellar light in a striking manner which also could not be were atmosphere to absorb the image gradually near the limb. If the moon, the sky would always be a night sky except the sun, with the stars—glowing steadily—visible right up to the edge. And one could see the larger asteroids, the great sky way the mysterious zodiacal light, (as more brightly in our earth, and even the prominences and corona of the sun. There would be no ocean of dust, haze, smoke, cloud, fog, and fog—no wind, no meteor no storms, no rainbow path, or any sound at all—and no twilight and dawn.

Resulting from the absence of air is another phenomenon the enormous temperature range from about 213 F where the sun is near the zenith, to about 240 below zero during lunar night. Likely there are no water bodies on the moon, as cannot detect sunlight reflected on them. And there would be no wind or water erosion on the surface. Altogether utterly desolate place, the moon shows no recognizable signs of habitation.

Cassini was, who first observed the moon in 1610 with telescope, and the satellite has held the attention of telescopists ever since. Of the early moon students, Hevelius published a chart of the whole surface. This chart was used for 100 years, and Hevelius was likely responsible for many of the names of the surface features. Riccioli published another map in 1651 replacing many of the earlier names with those of philosophers and scientists of the day. Of 200 of Riccioli's names for lunar formations are still in use. Since his time, many others have been added.

The large surface objects of the moon are the gray plains, or maria, the lunar mountain ranges, peaks, ridges, hills, the moat-walled plains or enclosures (such as Clavius) many of them effectively small plains the mountain-ringed plains (the Copernicus) the crater rings, craters and crater-pits; hills, ridges, valleys, and small features, and the bright rays.

The topographic feature largest on earth is the oceans, and next largest the continents. On the moon the large gray maria known to the ancients as seas correspond perhaps to oceans, or perhaps to the continents. It is difficult to make good analogy. It is easy to tell why the ancients called them seas, for they seem to have been covered with water once ago.

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According to the absence of air is another phenomenon the enormous temperature range from about 215° F. where the sun is near the zenith, to about -40° below zero during lunar night. Likely there are no water bodies on the moon, we cannot detect sunlight reflected on them. And there could be no wind or water erosion on the surface. Altogether utterly desolate place, the moon shows no recognizable signs of habitation.

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The topographic feature largest on earth is the ocean, and the next largest the continents. On the moon the large gray maria, or perhaps the continents, it is difficult to make good analogy. It is easy to tell why the ancients called them "oceans," for they seem to have been covered with water once upon

—or it may have been liquid lava (melted rock) Either water or lava appears to have overrun and melted and broken down many mountain ridges and left only remnants.

In the naming of the maria, the Latin designation of sea was used—*mare*—and the name for each denoted some thing fancied at the time. The original Latin names of the seas, etc., are still professionally used in astronomy even more than their English equivalents. Altogether there are about 20 of the gray areas. They include the following large maria:

Mare Crisium

Sea of Crises  
Sea of Fertility

Mare Imbrium

Sea of Storms  
Sea of Vapors

Largest of the above is the Oceanus Procellarum occupying the eastern regions of the moon. Besides these, there are of smaller maria like Mare Smythii (Smyth's Sea) Lacus Mortis (the Lake of Death) and Lacus Somniorum (the Lake of Dreams).

The "seas" are quite dissimilar in appearance as to size and extent. Small instruments indicate a level surface at most, but as the power is increased more and more irregularities become apparent in the form of depressions, ridges, hills, low, rills. The maria are darker than the rest of the moon; commonly the colors are different shades of gray and in the naked-eye view of the "man in the moon" is formed these darker areas appearing against the lighter surface.

Whether or not the maria were ever seas—now it is believed they are and for millions of years have been what we call plains. Probably much of their surface is arid, desolate, and forbidding, surely it is subject to greater extremes of heat than we ever know on earth. On account of their indefinite outlines in places, it is difficult to estimate the proportion of the total lunar surface occupied, but the best opinion is that more than half the surface is covered by them.

Mare Imbrium, a great elliptical plain 750 miles long, bounded on three sides by mountain ranges (the Carpathians, the lunar Apennines, the Alps) but the eastern side opens into the Oceanus Procellarum. Many other formations of great disparity of size are to be found in and around this region. Everywhere the surface exists at about the same level, although there are many low hills. Evidence

the surface. A particularly bright as well as rugged area near foot south of the mountain-walled plain Archimedes. In middle of the Alps is a remarkable feature of unknown origin, the Alpine Valley. It is a unique thing, a narrow row about 5 miles wide and 75 miles long, with various hills visible in a glass of good size. There is even a Mount Pe near-by.

The Straight Range is interesting, a series of L- or more like in one straight row about 45 miles long. This range can only be seen in high-power binoculars, together with the Jura Mountains, immediately west. Along the northern shore of Mare Imbrium is a beautifully curved "bay" known as the Sinus Iridum, which latter bay was probably not a bay at all by itself.

To the north, the bay is bounded by peaks rising 15,000 or more above the interior, and containing several craters. And at the ends of this range are two prominent features every conceivable linear topographic feature can be found in Mare Imbrium, the crater formations rising in all possible forms and sizes. Bright "rays" from Copernicus extend for miles over the plain.

The two hemispheres of the moon, northern and southern, differ widely (at least in the halves visible to us) as to topographical characters: the southern parts (the top in lunar maps and photos) showing an array of hundreds of separate, near-circular formations. Whereas the northern regions have great mountain ranges. The latter include the mountain belt surrounding Mare Imbrium, and the Haemus Mountains separating Mare Serenitatis from Mare Vaporum. Like these, there are other ranges scattered over the moon, such as the Alta Mountains, the Raphaela Mountains, and some spots at the moon's limb like the Leibnitz Mountains. The latter mountains present an irregular rim to the moon, especially noticed during a total eclipse of the sun, and giving it the "Baldy's head" appearance.

Mountain ranges on the moon have many peaks with an average height of 5,000 to 12,000 feet, and a few are considerably higher than that, as Mt. Huygens in the Apennines at 18,000 feet. The range bordering Sinus Iridum is very steep and high, as can be detected in the telescope under the proper lighting. Is the Leibnitz Mountains near the south pole, some of the peaks are used by the older telescopographers to be much higher, ranging 26,000 to 33,000 feet, a figure which now seems to be definitely overestimated. Compare these elevations with Mt. Everest, the highest peak on earth (29,000 feet), remembering that the moon is only about  $\frac{1}{4}$  the earth's



diameter so that, comparatively the mountains of the are considerably greater elevations.

The curved mountain ridges themselves are noticed in regions of the maria, running miles in all directions, & any discernible system. They appear to have rounded likely an example of erosion. Singularly enough, there many unexplained mysteries about our satellite. What it have been at work there to produce many of the features tingued even in a field-glass, we do not know. The are one of the examples of erosion they seem to be down as compared to their original height and shape. Rhiphaen Mountains are seemingly another example of it. There are also numerous isolated mountains, as well as that are dome shaped and many of the latter have craters their tops.

It has been the loose custom to call all the round crater objects simply craters. However they consist of several. The largest are the mountain-walled plains. The diameter from about 60 to 140 miles. Only roughly circular or polygon in shape, they are surrounded by mountain walls, which some cases rise little above the level of the surrounding. Yet they are impressive and conspicuous, for the inside depressed below the general level outside the ramparts enclosing walls. Clavius is the largest of all—being 140 across—but seen in perspective, near the south pole of moon, it may look smaller than Schickard and Grimaldus, near the middle of the moon is another of class. Inside Clavius can be seen a group of smaller rings, each 5 to 30 miles in diameter together with craterlets and elevations.

In some cases however as Archimedes in Mare Im the interior is not depressed below the surrounding plain. type of the class has low walls that are discontinuous presents runous or broken-down condition of these parts indicating probably they were once intact but since suffered erosion from either volcanic or activity.

The mountain ringed plains are the most numerous, are from 10 to 60 miles in diameter. They have practically circular ramparts, with walls uniformly high and steep inner slopes, which are terraced with wide regularly spaced ravines. The moon's face is literally littered with these formations, which are, as in the case of the details of the bright rays, seen best when on the telescope.

In all the ring-plains, the floors are uniformly depressed below the level of the surrounding wall. Most of the mountain-ringed plains, like Theophilus, Copernicus, Tycho, &

central peaks. The peak is ordinarily a composite rather than a simple one, so that the crater floors are rarely smooth. Central peaks are often found even when the entire "crater" wall, as with Heraclet. This object, located just north of great enclosure Proclus, is only about 23 miles in diameter. When the terminator—either the sunrise or sunset—is passing by this crater the latter is thrown into great relief and can be clearly seen with 15X binoculars. With a scope giving much greater magnification, it has "high, steep, circular walls, much terraced, and a fine central dome on the summit of which Schmidt shows a craterlet, a double crater and a craterlet on the crest of the north (Goodacre). Such is a fragment of typical description of lunar formations.

It is plain from observation that not all the craters have central peaks; why some do, and others do not, cannot be known. It is thought that in many cases the absence of a peak has been brought about by erosion, for very often a peak can still be observed; but in some, like Longomontanus and Clavius, there is definitely no central cone.

Crater-rings are a third type of round formations. They are 3 to 10 miles across, approximately. They are circular with only slightly depressed over the outside surface. In the inside is well depressed. Thousands of these small rings are scattered over the moon's surface with no systematic arrangement. Too small to appear on our moon chart (p. 14, page 76) they can be detected on photographs. Just one of these, Lenz, is shown on the map.

Craterlets are of the same nature as the crater-rings only smaller and are scattered indiscriminately over the surface. They are indeed so numerous as to render impossible an estimate of their number for inasmuch as they are very small they become more and more evident the higher the scope power used. Similarly crater-pits cover the surface in large numbers, being shallow depressions with ordinarily surrounding rims.

Crater-chains and chains of welled plains attract considerable attention, like the group starting with Heraclet and extending southward. Such are used as arguments both for and against the opposing theories of the moon's origin. A lunar ramp-plain is almost strictly an effect of erosion. Fra Mauro is an excellent example—a great plain in which the seaward rampart—as it were—has been linked to a chain of low hills with wide passes between them, on the plain here the original wall once existed. Many others show this effect in parts of the walls, such as the one and Proclus. Other minor features include twin

*craters multiple craters hilltop craters* The latter are most nearly like our terrestrial volcanic craters. They are common however and need high magnification. They are found on the tops of the central peaks of Walter a.

When the moon's crust cooled—so runs the idea held by some though not all astronomers—it shrank and cracked. Whether this is true or not, there are various *rills* or *ridges* found on the surface. Some are flat and broad and others narrow and deep as on the floor of Alphonsus. The most clearly visible is the large winding valley known as Schow Valley at the north end of Herodotus. Ordinarily it is of high optical magnification to see the rills, and various astronomers of note have identified hundreds of rills, especially under oblique lighting.

True well-defined lunar valleys are not very numerous. The best examples are the great Alpine Valley and the Rhea Valley. The Alpine Valley cuts directly into the Alps. Straight and wide, with steep cliffs it is possible that it may have been caused by a huge meteor striking at a very acute angle. The Rhea Valley is about 15 miles wide and extends for 10 miles it can be found northwest of the formation Fabrici. It is noticeably curved and the origin is probably very different from that of the Alpine Valley possibly subsidence of the land is responsible for the Rhea Valley. East of Ptolemaeus in the Mare Nubium, is one of the largest valleys on the moon another lies to the west of Herschel still other types of valleys are found on the ramparts of the mountain walled enclosures as in Cassendi.

Perhaps more mystery surrounds the nature of the *lunar rays* than any other single feature of the moon, for although they are clearly in evidence even in a small glass, their nature and origin are obscure. They consist of brilliant, narrow white streaks always emanating from some crater formation. At least 100 of them are known. Some extend for hundreds of miles over the surface before becoming finally lost. Evidently they are surface formations only and are probably never found on high elevations. They seem to proceed without regard to changes of level over which they pass. It is also clear that the rays manifest no change that can be detected.

Some of the largest of the bright ray systems are to be seen extending from Tycho Copernicus Kepler and Archimedes. Rays from Tycho are the largest and finest of all, some going as far as the outer boundary of Mare Nectaris. Crater-floors in the path of Tycho's rays show that the rays cross the crater formations hence we infer that the rays have been formed after the craters. The

## THE MOON

however they invariably lose in brightness. Some of my systems are composed of much shorter rays.

One knows the origin of these brilliant streaks. Perhaps they are occasioned by the deposition of crystalline dust on glass & terrible surface cracks.

A large range of light shadings, from heavy black drab to a dazzling white, exists on the moon, although average reflective power is that of dark rock. Aristarchus brightest spot on the moon, and Mare Humorum the

satellite seems generally to be composed of shades of gray & yet a few observers see other colors. This can have been distinguished on the Maria Humorum, Imbrium, and Serenitatis. It is also said that the Palus Somnii is golden-yellow to light brown blue, that Mare Frigoris is yellow-green and most remarkable of all, a dull reddish is supposed to have been seen once in a small crater. Truly perfect optical equipment is necessary to distinguish colors correctly—either reflecting telescope or a highly tested objective—as well as good seeing conditions of the sphere and good eye. Moreover terrestrial atmospheric conditions may not be confused with intrinsic lunar colors, nor we be confounded with "penumbral" shadow effects on the moon at certain times. Many expert observers never see special colors on the moon.

One knows yet how the moon's topographic features started. The two leading theories that attempt to account their origin are the volcanic idea (in which all the crater objects were formerly volcanic centers, and the gray is volcanic extrusions) and the meteoric hypothesis which says such formations resulted from the impact of meteors that fell to the moon's surface eons ago during the earlier stages of the lunar globe.

The commonest opinion held formerly was the volcanic one, but later Proctor argued that meteorites were responsible. At present opinion is probably about evenly divided between the two notions. An immense amount of discussion has taken place, with arguments and objections on each side. Against the volcanic theory is the objection of the form of typical lunar crater, which differs notably from a terrestrial volcano, the craters on the moon being hollow with no conical central mass. Also it is almost inconceivable that volcanoes nearly cover the surface of the moon, as it seems to be done, with 30,000 craters on our side of the surface, with the maria, whose forms are similar to the mountain-plains and so may have the same origin. Again, the

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## THE MOON

necessary to vaporize the meteorite is but a small  
as total energy and the surplus energy after vaporiz-  
meteorite is still over 400 times the energy of dynamic  
resulting prodigious explosion. There is no time for  
tion of heat, and little time for melting, but instead  
materials surrounding will be instantaneously pulverized  
shock. Like the "star dust" of Meteor Crater. The lesser  
on the moon would have the effect that for a certain  
of impact a surprisingly larger crater would be

idea of penetration of a meteorite below the surface  
be explosion and vaporization of the greater part of the  
is in accord with the views of Moulton, who claims that  
the reason why more of the supposedly hidden iron  
is not found in meteor craters. The great extent of  
view does not seem to be appreciated by scientists in  
ed. The explosion-meteor idea also explains best the  
lunar maria, here a larger meteor or perhaps a swarm  
base bodies, broke the crust. More important, it is believed,  
has been produced by a 4-mile-in-diameter meteor if  
it is 40 miles a second.

The dark color of the lunar seas is also best explained by  
theory. And lastly, the vexing question of the bright rays  
is to be more logically solved. Explosion by a meteor  
ing into the solid crust, perhaps in the subsurface liquid  
trial, first caused a cracked surface and then a wave of  
radiant pressure in the liquid that forced some of the  
trial into the cracks to condense around them at the  
site.

The moon is our nearest planetary neighbor to remain  
at a certain distance from the earth. From observations  
it has been determined that the mean distance of the moon  
to the earth is 238,857 miles; but the eccentricity of the  
orbit, or ratio by which it differs from a perfect circle, causes  
the distance to vary from 222,000 to 253,000 miles. This  
means that the moon is distant about 60 earth-radii. This  
fact should be remembered, rather than the usual  
pict showing the moon close to the earth. After the size  
and shape of the orbit are determined, it is not difficult to  
calculate the velocity of motion. This is about 2300 miles an  
hour in its orbit, and equal to the muzzle velocity of very  
high-power guns. The distance of the moon is such that the  
light angular velocity as seen from the earth is about 33'  
per hour so that the satellite moves over a space just a bit  
more than its own diameter every hour.

As the distance of the moon can be found by triangulation

craters are distributed indiscriminately not follow of crustal weakness as on the earth.

Goodacre claims that the presence of a large bright spots on the surface, of the type of the Linné is the best evidence of volcanic origin. At the center of the small crater from which it appears as if the white composing the rays has been ejected. Radiating ridges from Tycho also help in this idea.

Objections to the meteoric idea include the following arguments since the earth and moon have probably traveling together in the solar system since the "beginning" meteors should have fallen on each body alike, or they should have fallen correspondingly more on the earth than the moon, because of the larger size of the earth. Yet only a comparatively few meteoric gashes have been found on earth of which Meteor Crater is the largest. There seem to have been no traces left in the rocks to indicate "fossil" falls, or those antedating the present geology. Yet the presence of the earth's atmosphere would consume most meteors and hence they would not produce craters of gigantic size and number of craters on the moon is that the meteors would have been larger and more numerous than is held likely.

The *explosive meteoric theory* is a rather new form of meteoric idea and possibly has more in its favor than any of the other ones. According to the calculations of physicists a meteor moving at great velocity has so much kinetic energy that, when suddenly stopped, it explodes with unparalleled violence. At 40 miles per second according to Gifford, it has 400 times the energy of dynamite, and many of the meteorites come in with greater velocities than that. The question is why is there not a continued bombardment now like the ones which seemingly occurred in the past? If the number of meteors still coming to the earth's atmosphere millions of years is as great as is proved, what must the colossal "harvest" have been in the early eras, it is very probably the larger masses were all gathered up in the life history of the solar system so that only the smaller ones are now being drawn in—which appears reasonable. We seldom have large ones striking the earth although it is partly because they are consumed in the atmosphere.

It is held that if a meteor at 40 miles a second strikes the moon's surface (of lesser density than the earth's, and no atmosphere to resist the flight) and has its motion stopped in  $\frac{1}{10}$  second by the resistance of the globe it will penetrate about 2 miles below the surface. In the  $\frac{1}{10}$  second its "energy of translation" is transformed into motion of rotation.

Merchost	A Lullaba Mts.	M Moon Bridges
posicon	B Mare Australe	O Fraun. Heracles
astarchon	C Alai Mts.	P Alps
redobos	D Pyrenees Mts.	Q Alpine Valley
gler	E Mare Eclypsal	R Rhipace Mts.
gler	F Palus Somak	S Straight Wall
rocked	G Mare Humboldtianum	T Palus Putridus
rrd	H Harner Mts.	U Palus Volcanorum
krill	I Caucasus Mts.	V Carthartes
thrable	J Apennines	W Dörfl Mts.
sternb	K Carpathian Mts.	X Lacus Martis
krassos	L Straight Ranges	Y D'Alembert Mts.
zatos	M Promontory Laplace	

hods of surveyors, and as the diameter can be measured by the telescope, the size of the moon is easily derived. The meter is about 160 miles or over  $\frac{1}{4}$  that of the earth, the late area about  $\frac{1}{14}$  of the earth's, and the volume  $\frac{1}{49}$ . Though some of the other satellites in the solar system are larger than our moon, none is as large as our moon compared to its primary—the planet around which it revolves. The moon's density is 0.6 the earth's, or  $\frac{3}{5}$  times the density of the earth. The gravity at the surface is  $\frac{1}{6}$  that of the earth, so that a man weighing 175 pounds on the earth would weigh only 29 pounds on the moon (if weighed by a spring balance). If a man, contrary to the usual opinion, he could not jump six times as high in actual height, but could lift his center of gravity six times as high. Also an object thrown by one on the moon would go six times as far—and probably farther there being no wind resistance. Many curious phenomena would be observed in connection with such a small surface gravity. Of course all the light of our moon is reflected sunlight, there are no incandescent areas where it could be shining by its own light. The easiest method of proving this is to look at the dark invisible limb of the moon, which is in shadow. Here it is not illuminated by earthshine we see nothing of its surface. Besides this, an observation with the spectrograph proves that the light of the moon is similar in spectral character to sunlight, and thus proves its nature. Astronomers are often asked how our satellite compares with the sun in brightness. It is not an easy matter to measure the ratio, but the moon is weaker than most of us would expect. The average of the best photometer measurements shows that the full moon gives only  $\frac{1}{400,000}$  of the sun's brilliancy. For sunlight comes to the earth in a few seconds thus moonlight takes for one year. At the quarter phases, the earth receives only  $\frac{1}{16}$  as much light from the moon as from





Figure 14 CHART OF THE MOON

- |                 |                  |                 |
|-----------------|------------------|-----------------|
| 1 Schickard     | 19 Farnesius     | 37 Vendelinus   |
| 2 Schiller      | 20 Viter         | 38 Langrenus    |
| 3 Scheiner      | 21 Regiomontanus | 39 Macrobius    |
| 4 Longomontanus | 22 Purbach       | 40 Cleomedes    |
| 5 Wilhelm I     | 23 Arzachel      | 41 Gauss        |
| 6 Tycho         | 24 Alphonsus     | 42 Posidonius   |
| 7 Magnus        | 25 Ptolemaeus    | 43 Hercules     |
| 8 Clavius       | 26 Hipparchus    | 44 Atlas        |
| 9 Newton        | 27 Albategnius   | 45 Eudymus      |
| 10 Currier      | 28 Abulfeda      | 46 Golebchinski |
| 11 Stöfler      | 29 Catharina     | 47 Anstetich    |
| 12 Maurolycus   | 30 Cyrillus      | 48 Eudorus      |
| 13 Pitheus      | 31 Theophilus    | 49 C. und       |
| 14 Vlacco       | 32 Praetorius    | 50 Plat         |
| 15 Janssen      | 33 Saetheus      | 51 Aristillus   |
| 16 Fabricius    | 34 Petavius      | 52 A. tolychus  |
| 17 Zagul        | 35 Phillips      | 53 Archimedes   |
| 18 Piccolomini  | 36 W. Humboldt   | 54 Tycho        |

combined effect of the two motions is this: the retardation causes the moon to rise, on the average, about 50 minutes every night; and this retardation itself fluctuates with the declination of the moon.

When the moon is near the vernal equinox, the increasing declination day by day tends to lessen the normal retardation at rising time (for the northern hemisphere) but the retardation at setting is increased. In the southern hemisphere effects are the opposite. Similarly when the moon is near the autumnal equinox, the moonrise is later and later day by day to a large amount, but moonset is later each day to the minimum difference—in the northern hemisphere and opposite in the other hemisphere.

These phenomena of changing retardation of rising and setting moon occur each month and are most noticeable at the autumnal equinox. At the full moon at the vernal equinox, moonrise takes place nearly simultaneously with sunset. The moon's apparent path is now more nearly parallel to the horizon than at other times, so that as the sun goes down each day, it can be seen farther east and in its longitude, it will be comparatively near the horizon for several days afterwards. This is the harvest moon and gives us glorious twilight evenings—the nearest full moon to the time when the sun is at the autumnal equinox of September. The next moon is nearly the same, and goes by the appellation of beer's moon. In high latitudes the effect of the harvest and beer's moons is most pronounced.

In case the moon's ascending node corresponds with the vernal equinox, the moon's path (when the node is rising at eastern horizon) lies more nearly parallel yet with the horizon, and these extreme conditions prevail. In latitudes north of the earth's equator the harvest-moon conditions last at the vernal-equinox times, or spring in the northern hemisphere, but autumn in the southern latitudes.

Surprisingly enough, our satellite always presents nearly the same face to the earth, wherever it is in its orbit or whatever its place. It rotates on its axis in exactly the same period as its sidereal period around the earth, and rotation is in the same direction as the revolution. At first it seems to be difficult to understand that the moon can rotate at all, while always ruling one face to the earth, but if you walk around the room in a circle always facing the center of the room, you will find that you have been facing every direction of the room during the circuit, and have performed a rotation. The same reasoning holds with the moon; if the moon did not rotate on its axis, it could have to face always the same direc-

the sun Photographs prove that the moon is *yellowish*—contrary to popular ideas It would take five entirely filled with full moons to equal the sun's light

It is comparatively easy for anyone to get a good idea of the general movements of the moon in the heavens, as its movements appear to us that is, the apparent motion After the diurnal motion the apparent motion easiest to serve is the constant eastward motion against the background of distant stars When the moon is apparently near a fix or bright star its motion can be detected with the unaided eye, sometimes in an hour's time The eastward motion is detected by the noticeable retardation of rising each day for it rises perceptibly later every night (or day)

The eastward motion is evidence that the moon goes *slowly* around the earth in about a month The *sidereal period* is the time taken to pass from a certain star around the heavens and back to the same star Its average is  $27^d 7^h 43^m 11^s$  and is used as the sidereal month The *mean daily motion* is  $13^{\circ} 10' 58''$  Another revolution time of the moon is the *synodic period* or the time taken in moving from a certain position with respect to the sun around to the same relative position again as between two successive full moons This interval the *synodic month* is  $29^d 12^h 44^m 8^s$  It is the one most closely corresponding to our calendar month

Of course the times of rising and setting of the moon are of importance to everyone interested in this heavenly body Phenomena of rising and setting are complicated because of the fast eastward drift among the constellations and the variation in declination of the moon from day to day (caused by the inclination of the moon's orbit to the equator)

The moon in a month turns from north of the equator and now south—rising and setting at different latitudes of about one constellation in a day The first effect gives a change in declination It will be in the northern hemisphere as the north declination increases the moon is nearer to the north celestial pole The farther north it is the farther above the horizon becomes the moon The declination makes for an arctic circle and the moon is above the horizon of the corresponding hemisphere all the time. As if the observer be in the opposite hemisphere the moon is below the horizon and the moon is not visible at all The eastward motion of the moon is the cause of the increasing or decreasing moonlight per day

Although the daily motion of the moon is westward, the moon is *slowly* moving in the other direction (eastward) so that it takes about 13 days for a day between two successive moonrises, or 12 days for two moonsets. This is the *mean* interval

Time of immersion or emersion in good occultation work can be known accurately within 1 second. Radio time sent from the Naval Observatory station, an electric clock, reference, and logbooks are essentials. A list of predicted positions for our own latitude and longitude can be had in the American Ephemeris and some other professional periodicals, notably the *Nautical Almanac* (London). For the exact predicted time for a particular locality a good amount of computation has to be made with the given data, to fit the observer's station. Occultation work is more interesting than one would think, and observers become highly enthusiastic over it.

Eclipses of the moon are never missed by the enthusiastic astronomer. Suffice it to say that data are always given in the professional ephemerides. Commonly each eclipse presents features

from the average. As the moon enters the earth's shadow the stages are timed, and found to run close to prediction. The spectacle is often more beautiful and interesting than one would think. The color of the moon at different stages of the eclipse varies. Typically there is a real copper color cast over the moon at and near total. During mid-eclipse the surface may be more or less visible, from sunlight refracted and reflected from the atmosphere around the disc of the earth. Yet in some lunar eclipses the moon at mid-eclipse is so dark as to be invisible.

The curved shadow of the earth on our satellite constitutes partial proof of the general spherical form of our planet. In each eclipse is no proof because any object of circular cross-section might cast such a shadow. But if under every circumstance covering many eclipses, the shadow be observed to be circular the evidence is highly conclusive for sphericity of the globe.

When an eclipse of the moon begins we have first the event known as penumbral, which always occurs near the eastern limb of the moon, whereas solar eclipses begin at the western limb of the sun. This penumbral, or outer region of faint partial shadow can scarcely be detected near the beginning of an eclipse but as the eclipse progresses, it gradually becomes evident that the penumbral region is darkening as it nears the central section of the earth's shadow—the umbra.

This umbra is the full shadow and is quite dark. The unaided eye from the earth sees the umbra with sharp clear edges, but with low-power glasses the shadow appears somewhat diffuse, and high magnification prevents us entirely from defining the exact edge of the dark shadow. Duration of totality may be from nothing at all, where the eclipse is partial, or may range up to maximum of 1<sup>h</sup>40<sup>m</sup>. As to

tion in space and would then seem to us to turn, presenting all of its "sides" to us in the course of a revolution.

Actually though, a considerable portion of the surface at the edges is alternately visible and then away. Because of these "libration" effects of the moon does not always show precisely the same face as is but certain oscillations back and forth from a mean. Because of *libration in latitude* the observer from the earth sees 6° beyond one of the poles, and then half a lunar month later sees beyond the opposite pole by a similar amount.

*Libration in longitude* allows us to see around the eastern or western limb alternately about 7° 45' farther than mean, this motion putting into view at times certain places like Mare Smythii and Mare Humboldtianum, that lie at the extreme edge. At the opposite periods during the month each region can scarcely if at all be seen. For the moon's angular motion in orbit is variable because of orbital ellipticity while the rate of rotation is uniform. Near perigee its closest approach to the earth it revolves faster than average and accomplishes 90° in angular measure, or one-fourth of a revolution in less than one-fourth of the time its period of revolution.

Besides exploration of the moon's surface, certain special telescopic observations of interest may be made of other phenomena involving the moon such as occultations and eclipses. Moving along its prescribed path against the star background the moon frequently glides in front of a star or planet, hiding one of them from view. Inasmuch as the moon always moves (nearly) eastward in the sky the occulted object disappears behind the limb of the moon at immersion, and reappears on the western limb at emersion. A telescope is needed even for bright planets occulted, for the glare of the moon prevents the eye from noting the exact moment of disappearance or reappearance. And it must be remembered that an astronomical (inverting) telescope reverses the image top and bottom as well as left for side, so that a star appearing at the left of the moon to the naked eye will seem to be at the right in the telescope field.

Occultations give spectacular proof of the absence of lunar atmosphere, for the disappearance of a star is instantaneous; no gradual diminution of light occurs. It suddenly is invisible. Similarly at the calculated time the reappearance takes place in an equally startling manner. Good observations made with proper timing are of value to certain professional astronomers who encourage the work and who use the results for improving the data of celestial mechanics.

use of observation or otherwise in good occultation work. It can be known accurately within 1 second. Radio time is from the Naval Observatory station, an electric clock, telescope, and lunipathy are essential. A list of predicted eclipses for one's own latitude and longitude can be had in the *American Ephemeris* and some other professional periodicals, notably the *Nautical Almanac* (London). I get the exact predicted time for a particular locality, a full amount of compensation has to be made with the given  $\phi$ , to fit the observer's station. Occultation work is more tedious than one would think, and observers become fully enthusiastic over it.

Eclipses of the moon are never missed by the enthusiastic astronomer. Sufficient data are always given in the professional ephemerides. Commonly each eclipse presents features different from the average. As the moon enters the earth's shadow, the stages are noted, and found to run close to prediction. The spectacle is often more beautiful and interesting than one would think. The color of the moon at different stages of the eclipse varies. Typically there is a real copper color cast over the moon at mid-total. During mid-eclipse the surface may be more or less visible, from sunlight scattered and reflected from the atmosphere around the disc of the earth. Yet in some lunar eclipses the moon at mid-eclipse is so dark as to be invisible.

The curved shadow of the earth on our satellite constitutes partial proof of the general spherical form of our planet. In such eclipse is no proof, because any object of circular cross-section might cast such a shadow. But if under every circumstance concerning many eclipses, the shadow be observed to be circular the evidence is highly conclusive for sphericity of the globe.

When an eclipse of the moon begins we have first the event known as *penumbra*, which always occurs near the eastern limb of the moon, whereas solar eclipses begin at the western limb of the sun. This penumbra, or outer region of faint partial shadow can scarcely be detected when the beginning of eclipse but as the eclipse progresses, it gradually becomes distinct that the penumbra region is darkening as it nears a central section of the earth shadow—the umbra.

The umbra is the full shadow and is quite dark. The umbra, as seen from the earth with the umbra with sharp clear edges, but with low-power glasses the shadow appears somewhat diffuse, and high magnification prevents us entirely from defining the exact edge of the dark shadow. Observation of totality may be from nothing at all, when the eclipse is only partial, or may range up to a magnitude of  $1^{\circ}40'$ . As to

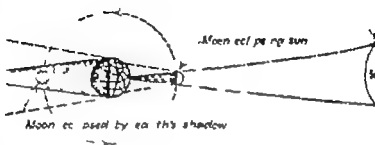


Figure 15

the duration of events, the moon may be in the first part of the penumbra an hour in the deep shadow  $1^{\circ}40'$  in the last part of the penumbra as long as an hour giving an extreme maximum period of about  $3^{\circ}40'$  for the phenomena.

Moon eclipses can be seen over half of the earth simultaneously although clocks in different time zones read different hours. Not only are the events visible wherever the moon is above the horizon but on account of rotation of the earth actually more than half of the globe is subject to a lunar eclipse. The whole half of the earth in moonlight is simply darkened during eclipse. The mechanics of solar eclipses are different, and the path of totality is a small strip across one part of the earth.

Eclipses of the moon are not nearly as important as those of the sun. The main value of lunar eclipses lies in the partial proof of the earth's form the opportunity for study of heat radiation at the moon's surface when eclipsed, and the spectacular effect it touches one's general astronomical interest to note the differences between various eclipses. They may be darker or lighter than the average depending upon the atmosphere around the earth's edge as seen from the moon and there are apt to be phenomena of lighting effects near the limb which are always unpredictable.

## 8. The Sun

TWENTY TWO and the earth are some 93,000,000 miles (nearly empty space, with the temperatures close to the absolute zero of  $-459^{\circ}\text{F}$ . But should you carelessly turn even small telescope on the sun without using a darkened sun-glass, it would burn your eye severely.

Which is in the nature both of a warning and of a commentary on the size and heat of this comparatively small star which makes life possible upon the earth. The sun is a huge ball of incandescent gases, measuring 865,380 miles in diameter. It would take a line of 109 earths to reach across its diameter (and more than 1,000,000 to equal its bulk).

But the planets wouldn't remain there long. They would fall into the body of the sun almost instantly unable to withstand the surface temperature of  $11,000^{\circ}\text{F}$ . The heat at the center of the star incidentally has been estimated at as much as 40,000,000. Under the conditions of heat and pressure at the sun's core, it is believed, atoms are unable to remain in what is to us their normal state.

These tiny building-blocks of matter are broken down, according to a popular version of one of the current theories, the electrons that revolve about the central nucleus, as the planets do about the sun, are stripped away and the nuclei are subjected to terrific mutual collisions. It is violent processes of this type, some astronomers believe that supply the heat and the heat and energy it pours out into space.

As it releases this energy the sun is at the same time giving away of its own mass and body. Every second over 4,000,000 tons of the star are poured off into the void, and so big is the force of it that scientists estimate it can continue at this rate for several billions of years—even if its resources are not supplemented in some manner from the outside.

The earth receives the thickest portion of this energy and yet, every schoolboy sooner or later discovers, the small amount falling on the surface of a magnifying glass is sufficient to ignite wood or start a fire when concentrated at the focus.

The surface of the sun (that which we see when observing with telescope or a telescope) is known as the photosphere.



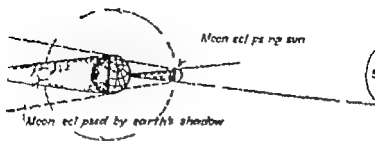


Figure 15

the duration of events, the moon may be in the first part of the penumbra an hour in the deep shadow  $1^h40^m$  in the last part of the penumbra as long as an hour giving an entire maximum period of about  $3^h40^m$  for the phenomena.

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## A The Sun

THE SUN AND THE EARTH ARE ABOUT 93,000,000 MI.  
APART. WITH THE TEMPERATURE CLOSE TO THE  
SURFACE OF THE SUN ABOUT 7000° F. BUT SHOULD YOU COME CLOSE ENOUGH  
TO THE SUN WITHOUT BEING A DISTURBED AND  
KILLED BY YOUR OWN RADIATION

Which is the eastern both of a winged and of a com-  
pact size and head of the corresponding small and  
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is the plane world? no the body of the sun

and the surface temperature of 1150°F. The test is the first of the type and has been scheduled as a preliminary

a 100% under the conditions of heat and pressure it  
can be a material, even by itself or mixed  
with other natural gas.

These are building-blocks of matter and form are  
 according to popular version of one of the great theories  
 he declares that on the whole the world is made of  
 atoms do about the size, are arranged in a regular  
 or subjected to periodic external influences. It is  
 even of this type, some astronomers believe that  
 the best and worst is part of the same  
 As it relates the same to the

As a witness to the story, the rest of the world has  
 pray of its own men and boys. Every man, every  
 one of the stars has passed it and the sun and the  
 world of life that we have known it to be. It  
 has for several millions of years—over a  
 billion—lived in the

The card reads: "The lowest person  
in the world is the one who is  
not a member of a church."

sphere. It is the first of four outer layers, and directly above it is the reversing layer surrounded by the chromosphere which in turn is enveloped by the sun's corona.

Down on the photosphere are the sun-spots. On some especially during the time of a sun-spot maximum, there are sun-spots large enough to be seen with the naked eye. These are the big ones, running perhaps from 50 000 to 150 000 miles in diameter over all into which a handful of earth could easily disappear. Almost any day during the maximum season as many as 25 smaller ones—still large enough to swallow our entire world—are visible in a 2 or 3 inch telescope, or even with a smaller glass.

The spots frequently swim through the sea of incandescent gases in pairs or clusters, and seem to move across the disc as the sun turns on its axis. They prefer solar latitudes between 5° and 40° both north and south and most live for only a few days.

Some, however, do stay longer and may even last through a full solar rotation of 25 days and still be going strong. Under higher magnification, the spots show a dark center known as the umbra and a lighter surrounding area called the penumbra. Umbrae generally run from a few thousand to 50 000 miles in diameter while the penumbras sometimes reach 150 000. The entire spot appears black against the background of the sun, but if it were not seen against the surrounding photosphere it would seem to be white hot, as really it is.

Scientists constantly discuss pro and con the possible effects of these sun-spots on daily life here on the earth. Although the precise effects may be debatable, there is little doubt that the appearance of great numbers of sun-spots in the course of the primary cycle of 11 years does have an influence on the weather, auroras, magnetic poles, radio reception, and perhaps even upon the normal course of human behavior.

What then is the nature of these spots which have so much to do with life on the earth? They seem to be magnetic storms on the surface of the sun, whirling about a center in a manner similar to cyclones on the earth although they are quite different. They are apparently associated with streaks of intense brightness known as faculae which are also located on the photosphere and are frequently observed in the vicinity of spots.

These faculae are visible in high-power binoculars, or in a 2 inch telescope, especially when observed near the edge of the sun, where the photosphere seems to be darker. They commonly seem to have longer lives than the associated spots.









## 9 The Comets

The excitement has been caused by comets than by any other objects that appear in the sky. Battles have been stopped, old-curses, proclamations have been issued, whole populations have been thrown into a panic, kings have abdicated in their throes, men have died of fear. Comets were considered for centuries as omens of death and destruction. People actually wore charms against them.

But all this is no wonder when you consider some of the spectacular comets that have been seen. There was one in 11 B.C. that was likened to a flaming torch, in 146 B.C. one as bright as the sun. In 530 A.D. a comet reached from horizon to zenith. The second comet to appear in 1811 possessed a head nearly 1,000,000 miles in diameter & with 1,000,000 miles in length. The comet of 1744 had six tails & a great fan, and the Great Comet of 1843 had a tail 1,000,000 miles in length.

It is not only their spectacular appearance that attracts attention, but also its frequent occurrence. At least 15 to 20 comets per century are visible to the casual observer & on the average, four wondrous ones appear every 100 years. In blessed time one may see several great comets and escape some others if he makes any effort to find them. In fact, sometimes as many as five come into telescopic view one year and often one of these is visible to the unaided eye. Many have been as brilliant as Venus and a few bright enough to be seen in the daytime.

Amateur astronomers find real enjoyment in keeping watch of comets, occasionally even discovering them and following them as long as they can be seen. The finding of a comet is a brain road to fame, for comets are named after their discoverers. Find a comet, and you have made your place in astronomical history. Pons found 27, Meader Swift, Barnard, Brooks, Perrine, and Olcott have each found 11 to 20 comets. In July of 1937 Flender's Comet attracted wide attention. In 1936 amateur astronomer Pettier found his fourth comet, in 1939 his fifth. Although professional astronomers have their telescopes are better equipped for comet discoveries,



visible. As the first speck of the sun returned to view illumination made it seem larger than it really was. The result effect was the formation of a diamond ring, with the edge of the sun as the diamond and the inner corona as the ring.

We would have had less to worry about, and far less to see, had we seen the eclipse simply as a partial one. Then it would have been a case of watching the moon pass across the face of the sun never reaching a point where it covered it completely. Just about all the amateur can do during a partial eclipse is to time first contact, the first time the moon first nicks the sun's edge, and last contact, when the moon leaves the disc. At intervals he can measure the percentage of the surface covered, measure the drop in temperature, watch the crescents projected by spaces between leaves and take photographs. The spectacle does not compare with that of a total eclipse but, as if in partial eclipses may be seen much more frequently.

Any solar eclipse in which the center of the moon passes over the center of the sun is known as a central eclipse, only when the eclipse is central can it be total. It can, however, be central and still not be total, for if the moon were so far from the earth at the time that it did not appear as big as the sun it would not cover the latter completely. At the moment of maximum eclipse, there would be a ring of sunlight surrounding the moon's disc, and no corona would be visible nor would the darkness of the heavens approach that during a total eclipse. This phenomenon is known as "annular" or "ring" eclipse, and while it is a striking spectacle, the practical observations for the amateur are substantially the same as those during a partial eclipse.

When the phenomenon is total, of course, he can do the same things and more. A total eclipse has two more "contacts" than has a partial one—second contact being when totality begins, third when it ends. The amateur can count and identify the stars that become visible; he should note the shape, position and number of prominences, the outline and color of the corona, the number of Bailey's beads, the width, speed, and direction of the shadow-bands. And always there is the possibility of a comet (otherwise invisible) appearing as the sky is darkened. The loss of light in the sky incidentally can be recorded with so simple an instrument as a photographer's photometer.

Thus the sun, which is visible every day and therefore offers the possibilities of observing its varying seasonal position, and which provides opportunities for daily telescopic observation, offers too one of the greatest spectacles that man can ever witness.



the amateurs with more time for comet-sweeping has surprising total to their credit.

Of course most comet-discoverers have used telescopes yet three railroad workmen in Africa were the first to see report the great Daylight Comet of 1910. Surely there is nothing to equal the great satisfaction of being the first to see one of these visitors from outer space, but it is also interesting to keep track of comets once they have been found.

Almost every month of the year there is some comet within reach of a telescope. Although the number per year may be small, perhaps three some comets can be followed for months or more. The *Handbook of the British Astronomical Association* annually lists search ephemerides for all comets scheduled to return during the year. The Harvard College Observatory *Announcement Cards* publish the positions of all comets. *Sky and Telescope* usually has current news of observable comets. Some expert on comets writes the monthly "Comet Notes" in *Popular Astronomy*. Almost every year a comet assumes naked-eye brilliance, and usually before it happens considerable publicity has been given it so that even the newspapers carry directions for finding it.

About every 25 years on the average one of the spectacular comets returns. These cause so much excitement that it is hard to escape notice of them. The Great Comet of 1811 attracted so much attention that a vintage of wine was named for it. It was so huge and so threatening that it was rumored among superstitious people that it might have caused the Great Lakes of America and the floods of Norway on its previous visit. Of course these geographic features were caused by other agents.

Most comets do return again and again. Many of them are regular members of the solar system and move in definite paths which focus around the sun. Some, with small orbits, return frequently. Encke's Comet, with its nearly circular path, returns every  $3\frac{1}{2}$  years. On the other hand, Halley's Comet moves in such a large and elongated ellipse that it averages about 76 years before coming back near the sun. When a comet reaches its nearest point to the sun, perihelion, it then starts out upon a journey that may carry it far beyond the most distant planet. Some 50 comets are known to have periods less than 100 years, while the comet of 1811 is estimated to require over 2,000,000 years to cover the vast extent of its orbit.

Some of the greater comets seem to appear from the depths of space, make one circuit of the sun on hairpin curves, then travel away again along almost straight lines.

are never to return again. Parabolic orbits have been added to many of these for which but one perihelion visit was recorded in thousands of years. Other famous comets are to have traveled in toward perihelion on the spreading of a hyperbola, a slightly different form of curve. It has been suggested that such comets as these move in a great curve, only a small part of which passes through the solar system, and that they may not belong to the system at all. Where these comets come from and whence they are and no one can say. They are not like the short-period comets with the latter's elliptical paths that are obvious members of the solar system.

Certainly our understanding is limited by our lack of knowledge of these celestial visitors. Were our life span longer, even man's historic stay upon this planet of a greater span, then we might have other records of the comets which now imagine to have made but one visit to our star. In recent studies have taken many comet paths from the aphelic and hyperbolic group (which would indicate that they are not members of the solar system) and added them to the elliptical one. No doubt many more of the exceptional comet paths will be established as ellipses as the years go on, many comets that we once considered visitors from elsewhere have proved to be regular members of the system.

And right here is the important reason for the rigorous study of comets, and the year-by-year check of their paths. For only by the most exhaustive study of each comet that crosses our way shall we be able to understand the relation of these wandering visitors to the sun and the solar family. The amateur can make substantial contributions to comet fact and theory by doing his part in this night school. Day-by-day charts of the comet's position, its changing place among the stars, sketches and measurements of head and tail, and photographs are important.

Even though some comets are accredited members of the solar family they have many characteristics that are quite different from other members of the group. Their forms are ever changing, while planets are constant. Comets are lit partly by their own light and partly by reflected sunlight. While planets are illuminated only by sunlight. The orbits of most periodic comets are greatly elongated, while planets move in almost perfect circles. Comets may come from any direction and any angle to go round the sun, while planets all move in nearly the same plane in space and go around the sun in the same direction.

One of these differences has its effect on the appearance of a comet as we see it in the sky. Usually when the comet

first appears it is a hazy patch with no well-defined (except the head or coma. Coma is the Latin word and comets in both early and late stages correspond the name. The coma of a comet is the roundish region. The head region includes not only the coma, and envelopes but also the nucleus if present. The head been observed to be 30 000 to 1 000 000 miles in

As the comet comes within about 250 000,000 the sun, it seems to undergo some excitation. It suffers first of sometimes endless and startling changes. The brightens, and in most comets a brilliant nucleus appears it. Then the coma expands and its material often back away from the sun to form a tail. Probably it is the radiation pressure of the sun that drives the coma material. There are comets that never go through these changes our observation and never show more than a fuzzy ball. There are others though that produce jets and streams from the coma and throw off sheath after sheath from head. Sometimes the head seems surrounded by hard envelopes. Coggia's Comet displayed magnificent envelopes. The light from a comet's nucleus is reflected sunlight, while the coma and tail are probably sunlight absorbed and re-emitted by gaseous molecules.

In certain comets the changes have followed in great numbers and with amazing rapidity. Donati's Comet for instance threw off seven envelopes in just a few days. Tebbutt's Comet of 1861 shed 11 envelopes in weeks. Morehouse's Comet 1908 is the comet most famous for the changes in its head and tail. It seemed to require but a few hours to release its clouds of material.

Not all comets have nuclei but a great many of them do. Sometimes the comet nucleus is less than 100 miles wide but the one in 1881 was 50 000 miles in diameter. In nuclei appear as a single brilliant star like center in the head but in the comet of 1881 there were six or eight "knots" luminous material. Very often the nucleus appears to come and grow brighter just before the appearance of envelopes. This change was noted in Donati's Comet some 4 to 7 hours before the sheaths appeared and in Morehouse's but a few hours preceding. Here is where the amateur astronomer can render his greatest service—in keeping record of all changes that come from hour to hour and day to day.

Normally then a comet first appears with only the coma in view. Within this by careful observation we may frequently but not always be able to discover a nucleus. Watching the nucleus he may find variations in its brightness and its size. These may be warnings of even greater changes.

A few hours or a few days thereafter nebulousity may appear, tenuous envelopes may appear to issue from the head and then drift back to form the tail.

The tail is by far the most spectacular of the comet's features. It may be millions of miles in length and extend a larger area than any other celestial body except a giant star, a star cluster or an entire galaxy. Comet 1911 possessed a tail 4,000,000 miles in length, stretching 105° across the sky. Donati's Comet had a tail nearly of that length, and the Great Comet of 1843 possessed a (as mentioned before) of nearly 100,000,000 miles. In 1823 the Great Comet of that year had a tail only second to that of 1843.

The tails of comets are curious phenomena. Often the glister stars visible to the naked eye have been mentioned visible through a comet. On one photographic plate 140 stars were counted 73 stars of twelfth and thirteenth magnitude visible through the tail of the Pons-Winnecke Comet. Comets must be extremely tenuous in nature and, despite their tremendous size, not massive at all. Probably the heads of comets are loose meteoric particles, the outer regions of which are stirred out by evaporation, forced back by radiation pressure of the sun, and dissipated into microscopic fragments to form the tail. Scattered over a tremendous area, tiny particles being perhaps a mile apart, so that a comet's head is almost a vacuum, more tenuous than the air. It has been suggested that the carbonized and ultra-carbonized gases of comets contain and the tiny particles that compose the tails are probably illuminated by the shock of electrons from the sun. The tails themselves may actually be hollow cylinders, envelopes trailing back like a shepherd's flock, and the material is lost to the comet forever.

Tails of comets have assumed the greatest variety of form. Some are short and stubby and some, as already suggested, extremely long. The great comet of 1744, De Chéseaux's, had six tails visible to the naked eye. Bielly's of 1903 had a tail barely distinguishable on the photographic plate. But ill-defined tails followed the comet of 1841 enclosing within them some 3 separate rays. In 1823 a comet had two tails separated by 160°.

Strangely enough the tails, although they follow the comets on their outward journey wheel about as perfection—their best approach to the sun—so that a line from the sun to the comet runs almost through the tail. Then, however, the tail seems to gain on the comet and after perihelion, leads as the comet leaves the sun and starts toward outer regions. The tail is slightly lag, so the tail is seldom exactly on a straight

line from sun to comet head except when far away sun. As the comet approaches the sun the tail is behind the straight line as the comet leaves, it is still this radius vector—although now it begins to comet head.

Once in a while comets come extremely close to or the sun. In 1680 Newton's Comet went within corona of the sun, 147 000 miles from the surface. a great comet went directly between the earth and in transit. The earth on the other hand went right the tail of Tebbutt's Comet on June 30 1861 & the watch for any strange sight, as our planet passed the comet's tail reported a peculiar glow in the faint phosphorescence. And again on May 19 1 earth passed right through the outer regions of Halley's Comet. Knowing this, a number of made careful observations and measurements night On this occasion they saw nothing, & measured nothing felt nothing to indicate the comet.

Evidently a comet's tail can do the earth no solid meteoric particles of a comet's head a minor earthquake or actually dig a great hole strike the surface of the planet, or a "tidal wave" the sea. It is thought that the huge meteor crater was caused by an encounter with a small (of separate fragments) being 400 feet across.

Comet-observing is, in the main, of two comet-seeking a deliberate attempt of the discover new comets. No one knows when a appear in the sky even a great comet. Many h without results nevertheless, many comets covered by patient comet hunting.

For comet-seeking, small areas of the sky with utmost care noting and checking on ever nebula, and hazy object. The greatest chance lies near the ecliptic, and in the evening sky also in the morning sky before sunrise. An aperture with magnification of about

field. Examine the sky object inasmuch as some were first but a "star" Great observers advise it than a large it looks like like

object's position with that of known objects on the chart.  
 star rise, like Venus or Saturn, will include the comet  
 of retrace down to about north equinox, and for a  
 good work Dyer's New General Catalogue together with  
 Index Catalogue is really the last word. If your exposure  
 of light is not on any of the star fields, the chances are  
 you have found comet.

Careful observation for another night and accurate study  
 its position each time will help to eliminate doubt. But its  
 place in extreme case and estimate its magnitude by  
 comparison with some neighboring stars. If the exposure  
 has been shifted its position you need doubt no longer. If  
 it is an ordinary star where you live, or some person  
 is especially interested in comets, you might take one  
 for precaution. The staff at the observatory might know  
 what the comet is a new one or not unknown, or an old  
 returning and already under observation. If the comet  
 field is unknown to them, write to your man. Send a  
 request to Harvard College Observatory describing its loca-  
 tion and magnitude, and also send for the discovery of a  
 comet.

The second type of comet-hunting is the picking up of  
 less easily discovered. Here the comet can be found  
 just before it is too close to be seen, and if the  
 position of the comet is within the power of the instru-  
 ment. The principal tool needed besides the telescope is an  
 accurate star position of the object at distance comet.  
 For the comet magnitude is 4 or brighter, the position  
 is placed at once on a star chart of visible stars and  
 the star is located. To see for better comet, proceed  
 it is in the case of finding comets (as described in the  
 second chapter).

Because of the very nature of comets, they were long  
 considered one class in the firm and were long (as  
 is to be seen) and telescopes, for the same reason of  
 its history is spread over a long time. Sometimes, their  
 observations are necessarily preliminary and  
 position are accurate to locate the comet head, and  
 finding out of most comets with the telescope. It is  
 only best to see how given and will be. The greater  
 light-gathering power the more details observable in  
 comet tail and faint envelope. Just as one can see more  
 than in a 10-inch than in a 3-inch telescope, so one can  
 see more in a 10-inch than in a 3-inch telescope.  
 Then are really many things that one can observe when a  
 comet appears in position day by day. Brightness, shape, size  
 and position, appearance of coma, number of satellites.



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Evidently a comet's tail can do the earth no harm. The solid meteoric particles of a comet's head might produce minor earthquake or actually dig a great hole if it should strike the surface of the planet, or a "tidal wave" if it struck the sea. It is thought that the huge meteor crater in Arizona was caused by an encounter with a small comet, the nucleus (of separate fragments) being 400 feet across.

Comet-observing is, in the main, of two types. First, comet seeking—a deliberate attempt of the telescope-user to discover new comets. No one knows when a new one will appear in the sky even a great comet. Many hours are wasted without results nevertheless, many comets have been discovered by patient comet-hunting.

For comet seeking, small areas of the sky are examined with utmost care noting and checking on every star cluster, nebula, and hazy object. The greatest chance of finding a comet lies near the ecliptic, and in the evening sky after sunset, and also in the morning sky before sunrise. An aperture of 4 to 6 inches is preferable with magnification of about 30 diameters and a fairly wide field. Examine the sky minutely studying every suspicious object, inasmuch as some of the faintest visual comets discovered were first but a "stain" on the background of the sky. Great observers advise that it is better to examine a small region closely than a larger area hurriedly.

When a comet first appears it looks like a hazy patch of light. At first glance one could take it for a star cluster or nebula. This is the time to get out an atlas and compare it

object's position with that of known objects on the chart. Star atlas, like Norton or Schurig, will include the clusters nebulae down to about ninth magnitude, and for actual work Dyer's *New General Catalogue* together with *Index Catalogue* is really the last word. If your suspicious object of light is not on any of the star fields, the chances are you have found a comet.

Useful observation for another night and accurate study of position each time will help to eliminate doubt. Plot its position with extreme care and estimate its magnitude by comparison with some neighboring cluster. If the supposed comet has shifted its position you need doubt no longer. If there is an observatory near where you live, or some person who is especially interested in comets, you might take one word of precaution. The staff at the observatory might know whether the comet is a new one as yet unknown, or an old returning and already under observation. If the comet could be unknown to them, waste no more time. Send a gram to Harvard College Observatory describing its location and brightness, and claim credit for the discovery of a comet.

The second type of comet-observing is the picking up of comets already discovered. Here the comets can be found almost at will if the sky conditions are suitable and if the altitude of the comet be within the power of the instrument. The principal tool needed besides the telescope is an ephemeris, giving positions of the object at definite times. From the comet's magnitude is 6 or brighter the positions may be plotted at once on a star chart of visible stars, and then then be located with ease. For fainter comets, proceed as in the case of finding asteroids (as described in the second chapter).

Because of the very nature of comets, they seem brighter to the unaided eye than in the glass and appear less defined than in binoculars and telescopes, for the same amount of light intensity is spread over a larger area. Sometimes, therefore, naked-eye observations are surprisingly satisfactory and binoculars are adequate to detect the nucleus, head, and trailing tails of most comets. With the telescope, it is usually best to use low powers and wide field. The greater the light-gathering power the more details observable in the comet's tail, and fuzzy envelopes. Just as one can see more stars in a 10-inch than in a 3-inch telescope, so one finds more light in comet images when he uses greater aperture. There are really many things that one can observe when a comet appears its position day by day, brightness, shape, the head, nucleus, appearance of coma, number of envelopes,

changes in the tail number of tails color any features or for that comet and change of velocity as it approaches and then leaves the vicinity of the sun

Often when a comet is first observed its passage is a slow and serene one. It takes careful observation to detect any change in its location from night to night. As the comet approaches perihelion its rate of travel increases. Just as earth moves most rapidly when nearest to the sun, and moon most swiftly when nearest to the earth, so comets, following the same laws of gravitation, speed up as they close to the sun.

Any comet that is brilliant and spectacular is commonly known by the name of its discoverer. It always bears a name too to indicate the comet's place in order of discovery for the year or the time of its perihelion passage among the comets of that year. Thus Donati's Comet in 1858 is called Comet 1858 f for the order of its discovery and Comet 1858 VI for the order of its perihelion passage. There are also Di Vico's (1846 IV) Coggia's (1874 III) Swift's (1874 I) Kopff's (1906 IV) and numerous others.

Occasionally there comes a comet like Morehouse's 1908 which changed so rapidly from night to night that one could hardly imagine it the same object. Now and then arrive a comet like the Great Comet of 1882, which was visible for 9 months and was known to transit the sun in a while we may see another like the Great Comet of 1811 which threw off 11 envelopes from its tail. Surely there will be others visible in the daytime and about four times in a century one brilliant enough to attract observers all over the world.

There may be another like Biela's which split in two before the eyes of an observer in 1845. Seven years later the two sections returned still farther apart but still traveling in the old orbit. Then when the next approach was eagerly anticipated, the comet could not be found at all. In its place, however, appeared a shower of meteors. Since that time other meteor showers have been associated with the periods and orbits of old comets which have disappeared.

There are the cases of Tempel's Comet of 1866 and Leonida's of November, Tuttle's Comet of 1862 and the Perseids of August. Biela's Comet and the Andromedids of November. It would appear that comets do represent an aggregate of meteoric materials which, disintegrating, often give rise to a periodic shower of shooting stars.

## 10 The Meteors

Throughout interplanetary space there are countless pieces of stone and iron most of them wheeling about the sun in elliptical paths and some apparently sweeping into the solar system from the depths of interstellar space. On an average they are no bigger than a few grains of sand, but there are those that are enormous and weigh tons.

More than 100,000,000 of them bombard the earth every day pouring down on the atmosphere in a constant stream. Were it not for our surrounding blanket of air they would hit the ground in a ceaseless barrage. As it is, these meteors, as they are called, are vaporized or burned to a fine dust by heat resulting from friction with the air and settle perceptibly through the atmosphere to add themselves to the soil bank of the earth. We see them usually for only a few seconds. As the heat has vaporized their surfaces into luminous light-emitting envelopes that appear much larger and more brilliant than the original object. Almost immediately after their fleeting glimpse, the average meteor is gone and there seems "nothing but a shooting star."

But we see only a few perhaps a half-dozen per hour in ordinary nights watching by one person. The rest are never known because they fall over the oceans and deserts or other uninhabited areas that take up so much of the earth's surface. Or because they come in the daytime, or are hidden by clouds, and so escape notice. Only the brighter ones are visible to the unaided eye, of course and even observed at one location will see only a small portion of those plying the earth at any one time—which are additional to those accounting for the comparatively small number seen. Occasionally one is bright enough to be seen in the day time, and may even explode somewhere in its path. Such an appearance as that, whether it comes during the night or day (usually called fire-ball, and is fact any "shooting star" is brighter in brightness than that of Jupiter or Venus is something many times larger and brighter than the full moon classified generally as fire-ball. The term "bolide usually denotes an exploding meteor. The phenomenon is termed

changes in the tail number of tails, color any features on for that comet and change of velocity as it approaches then leaves the vicinity of the sun.

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There are the cases of Tempel's Comet of 1866 and the Leonids of November, Tuttle's Comet of 1867 and the Perseids of August, Biela's Comet and the Andromedids of November. It would appear that comets do represent an aggregate of meteoric materials which disintegrating often give rise to periodic shower of shooting stars.

Let us on a star map and traced backward, nearly all seem to emanate from the same section of the sky. The shower is named, usually, from the constellation in or near to this radiant point, seem to lie, and the swarm of meteors which apparently diverged from the constellation is known as the Leonid shower.

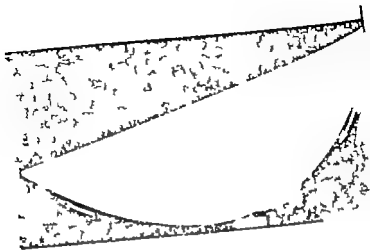
The radiation effect, by which the meteors of a shower seem to emanate from a point, is only an optical illusion, an indirect radiation that has no connection whatever with the point that lies about it. The meteors appear in the atmosphere at heights that average from 40 to 50 miles above the earth, billions of miles away from us. The impression that they radiate, then, is the effect we obtain when we view those

traveling toward us in parallel paths. Just as when standing between railroad tracks and looking at the distant tracks seem to come together so do these parallel meteor paths, traced backward, seem to come together as if radiating from a point.

In the case of the Leonids, and they are fairly typical, there is a regular display of shooting stars every year in November which occurs as the earth travels through the stream of orbit that intersects the path of the meteor group. Every 33 years the main body of the stream is at the position and a major shower occurs. The meteors, obviously, are not distributed evenly along their orbits, and even the main swarm may vary in its date of appearance because of perturbations induced in its path by the gravitational attraction of the planets. The Leonids, for instance, have failed in their "major" appearances to produce anything remotely like the fine spectacles of 1833 and 1866 even though showers of 1931 and 1933 produced results far beyond normal average for all years.

The other meteor showers, similar in nature to the above, have never within recorded history of such events, produced a celestial show as have the Leonids, but there are a number that offer annual spectacles during which the observer may see several hundred meteors in the course of a night. Perhaps the richest and most consistent of these is the Eta Aquarid which appears to visit the earth, during a full month, from July 15 onward. It reaches its peak about August 12, when perhaps 50 to 100 meteors an hour may be seen after midnight, apparently emanating from the constellation of Pegasus.

But we don't have to wait for meteor showers to watch meteors from interplanetary—and interstellar—space streak across our skies. They are constantly arriving and leaving which on the sky will almost always result in seeing a



on a star map and traced backward, nearly all seem to come from the same section of the sky. The shower is named usually from the constellation in or near this radiant point seems to lie, and the stars of which apparently diverged from the constellation of it known as the Leonid shower.

A radiation effect, by which the meteors of a shower to emanate from a point, is only an optical illusion, an effect of perspective that has no connection whatever with the actual fact about it. The meteors appear in the atmosphere right at average from 60 to 80 miles, while the stars are millions of miles away from us. The impression that there is a common point from which they appear to emanate, then, is the effect we obtain when we view these meteors as if they were moving toward us in parallel paths. Just as, when we stand between railroad tracks and look off to the distance, tracks seem to come together so do these parallel meteor paths seem to come together and seem to come together in a radiant point.

In the case of the Leonids, and they are fairly typical, there is a regular display of shooting stars every year in November which occurs as the earth travels through the portion of orbit that intersects the path of the meteor group. But by 73 the main body of the meteors is at the inner part of the orbit and the meteor shower occurs. The meteors, obviously, are not distributed evenly along their orbit, and even the main body of the meteor shower is not so dense as it appears because of gaps induced in its path by the gravitational attraction of the planets. The Leonids, for instance, have failed in their major appearances to produce anything remotely resembling the fine spectacle of 1833 and 1866 even though the showers of 1911 and 1912 produced results far beyond normal range for all stars.

The other meteor showers, similar in nature to the above, have a much less recorded history of such events, produced by showers of meteoroids as in the case of the Leonids but they are a shower that offer annual spectacles during which the observer may see several hundred meteors in the course of a few hours. Perhaps the most common and most consistent of these is the Perseid which appears to visit the earth during a full month from July 1 to August 12, peaking at peak about August 10-11. Even perhaps 10 to 100 meteors an hour may be seen after midnight appearing emanating from the constellation of Perseus.

And we do not have to wait for meteor showers to watch the sky. (on interplanetary—and interstellar—space) and see the stars. They are constantly arriving, and as we watch on (the sky) will almost always result in seeing a



few The latter half of the year from July onward, seem to be the best time to look for them, for during that time the average number of meteors visible (10 to 15 an hour near midnight) is nearly double the average number per hour per hour of the first 6 months (5 to 8 an hour near midnight) And in addition an observer will see twice as many shooting stars from midnight to 6 a.m. as he will from 6 p.m. to midnight.

The latter fact is easily explained, for in the evening we are on the rear of the earth as it speeds in its orbit around the sun. But in the morning, we have been spun around so that we are on the front or advancing half of the planet. Meteors we see in the evening have to catch up with us, while those we see in the morning we meet head on. There are only more of these then but when they are in the atmosphere they are traveling much faster than those of the evening. And since velocity is an important factor in determining the brightness of a meteor those seen in the morning will naturally be brighter than the ones seen earlier in the night.

In the atmosphere the speeds of meteors range from 9 to 40 miles per second, and what happens at this speed happens in an instant. The friction of the air with moving objects in our normal experience has little effect other than to reduce speed. But at the velocity of a meteor it is sufficient to raise the surface temperature of the object to white heat. The brilliancy of the tiny objects is explained by the fact that the surface is spurted forming a luminous gaseous envelope which stands out against the dark sky. Since meteors are usually small, most of them are burnt out miles above the ground.

Most meteors disappear at an altitude of 40 miles, having first become visible at from 60 to 80 miles (30 to 100 miles for fire-balls). This is true even if the object has not been burned away for the air retards its speed steadily so that the meteor is large enough to reach the earth. It does not usually with merely the speed of an object falling freely from a considerable height. It probably will not be glowing as it drops to the ground, and it may even be cool to the touch immediately afterward—because the friction generated before affects only a thin layer of the outer surface which can cool rapidly. The interior of the stone is deadly cold and there is not time for the surface to become hot.

Because a meteor of 40 miles is usually to the

ble at an average will ever stay

Observers can be of considerable assistance to the astronomer in recording their observations of meteors, even if the records they make be only of an occasional but real meteor for some other amateur in some other locality have seen the same object. By putting the two records together scientists can tell a good deal about the meteor.

One of the best and most valuable methods of observation is in which two observers take up positions miles apart to watch the same section of the sky. Adequate observations from two such separated points will enable astronomers to judge the height and path of meteors seen by both persons. This work, naturally presupposes a good knowledge of the positions.

The two observers should be stationed not less than 20 miles apart, to provide a good base-line for computations. They should be more than 100 miles distant from each other. Dr. Charles P. Olivier, one of the world's foremost authorities on meteoric astronomy recommends a base-line from 40 to 60 miles. The necessary equipment consists of accurate timepiece and a celestial globe or a good set of star charts. A ruler will prove very useful.

What is most desired in such observations is the path of meteor across the heavens, lined as accurately as possible to the hour minute, and, if practicable the second. The ruler held at arm's length, will help in trying to fix exactly the path of the meteor along the stars after it has vanished. It is of great importance to determine as exactly as possible the point at which the meteor was first seen and the point at which it disappeared. This can be done, of course, in relation to the stars near which it passed, and the terminal points of the path indicated in distance (in degrees) from or between certain stars or star configurations. It will always prove easier to determine the end of the path than the beginning, for the sudden appearance of meteor at any particular time is unpredictable.

To make the observations of the greatest possible value, the meteor path should be marked accurately on star chart, either with an arrow indicating direction of flight, and the chart should be numbered. With this record should be kept tabulation, giving the number of the meteor on the chart, the point near which it began and ended, its direction, brightness, color, speed (fast, medium, or slow) and comments concerning any train it might have left in its wake and how it is listed, together with remarks about any other unusual characteristics the meteor may have displayed, such as an explosion or other sound. It is more than worth while, too,



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the estimate of brightness, as usual.

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can be made.

The first consideration should be to compare it with the  
flint of the region. Often the ~~meteorite~~ meteorite can be  
immediately eliminated on the basis of ~~color~~ color. Be-  
cause of their unusual light weight ~~compared~~ compared  
don't be fooled by a piece of flint or ~~other~~ other material  
it deceives because ~~it~~ it is ~~perfectly~~ perfectly smooth and  
they are largely stone, and ~~that~~ that type common to the  
terrestrial. Because the stones are ~~more~~ more numerous they  
are most frequently found ~~in~~ in ~~the~~ the ~~vicinity~~ vicinity with a  
disposition, is apt to occur ~~in~~ in ~~the~~ the ~~vicinity~~ vicinity  
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for the observer to note sky conditions at the time, to with a candid statement as to how accurately he feels he made his observations.

But this is far from the only way in which the *amateur* may make useful records for the professional, even tho it is perhaps the most difficult and exacting method. Observations made by one or two persons working together at simply charting the paths of the meteors of a particular show or of an evening are valuable in helping to study *radiants*. Not all meteor *radiants* remain in one fixed position *amid* the stars, and research on the slight shifts occurring in *that* of a particular shower may reveal extremely interesting *facts* about meteor distribution.

In working to determine the radiant of a meteor *display* the precise direction of the paths of meteors in the *region* is needed above everything else. A slight error in *indicating* the beginning and ending points in the meteor paths will alter the determination of the radiant, but the paths *should* be charted accurately and with an arrow-head indicating direction of fall.

The whole process, including a tabulation containing material listed above, can be run through for each set experts find, in about a minute.

If all this seems too much, or beyond your knowledge of the constellations (which such work will inevitably *improve* by the way) then you can still be of help to science. Merely counting the number of meteors seen per hour is *of* value in aiding the determination of the density of the *meteor* stream. Better work might be done perhaps by counting number seen at 5-minute intervals over a considerable *period* of time.

It will always prove of value to observe as carefully possible the trains left by brilliant meteors. Estimates of brilliance, colors, duration, direction, width, and drift *through* the air can be made. And field glasses or binoculars *will* enable the watcher to follow the train for an appreciable length of time after it has become invisible to the naked *eye*. The train, also known as the afterglow, is a luminous *phenomenon* in the path of the meteor generally presumed to be an *electrical* phenomenon resulting from ionization of the air *through* which the burning body has passed.

When a rare daylight meteor bursts into view fix its position as accurately as possible in relation to near-by houses, poles or trees, and mark the spot at which you are standing. Then measure the path later in altitude and azimuth, using quadrant or protractor and note any other details. Six records will help in fixing the path of the meteor in the *sky*.

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Some meteors which actually reach the surface of the earth are the only celestial objects we can touch and analyze in our laboratories. They are important. They show elements similar to those of the earth and furnish clues to the conditions of space. In other words, they are well worth studying. Looking for meteorites is actually another field of observation—one that requires one's every-day powers of observation, rather than the watching of the heavens. Frequently observers find several pieces of stone which they take to be rocks and excitedly proclaim as such. Be cautious and examine the object for certain characteristics before rushing to the laboratory—which is the only place where a final decision may be made.

The first consideration should be to compare it with the rocks of the region. Often the supposed meteorite can be immediately eliminated on this basis. Iron meteorites, because of their unusual weight, usually distinguish themselves, and do not be looked by pieces of slag or cast iron. Meteorites are deceiving because some are predominantly iron while others are largely stone and third type combines the two materials. Because the iron ones are easier to recognize they are more frequently found. But a bolide, exploding with a great detonation, apt to scatter dozens of stone fragments from a small area.

Meteorites usually bear a coating on the surface which makes them rustling as they pass through the atmosphere. This coating, which is extremely thin, has the appearance of black crust or varnish, and is sometimes dull or grayish in color. The surfaces of most meteorites, moreover, show ridges or furrows that result from unequal melting of the surface in this same passage through the air. Those cavities on the front (as the meteor traveled) are small and deep while those on the rear are broad and shallow. Eventually the weathering effects of rain and wind cause the pits to become deeper and the crust to disappear with the formation of iron oxide, or rust.

Often meteorites are found on the surface of the ground,

for the observer to note sky conditions at the time, kept with a candid statement as to how accurately he feels he made his observations.

But this is far from the only way in which the amateur may make useful records for the professional, even if it is perhaps the most difficult and exacting method. Observations made by one or two persons working together simply charting the paths of the meteors of a particular shower or of an evening are valuable in helping to study them. Not all meteor radiant positions remain in one fixed position among the stars, and research on the slight shifts occurring in the position of a particular shower may reveal extremely interesting facts about meteor distribution.

In working to determine the radiant of a meteor shower, the precise direction of the paths of meteors in the sky is needed above everything else. A slight error in indicating the beginning and ending points in the meteor paths will affect the determination of the radiant, but the paths should be charted accurately and with an arrow-head indicating the direction of fall.

The whole process, including a tabulation containing the material listed above can be run through for each meteor shower in about a minute.

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It will always prove of value to observe as carefully as possible the trains left by brilliant meteors. Estimates of their brilliancy, colors, duration, direction, width and drift through the air can be made. And field-glasses or binoculars will enable the watcher to follow the train for an appreciable length of time after it has become invisible to the naked eye. The train, also known as the afterglow, is a luminous trail in the path of the meteor generally presumed to be an electrical phenomenon resulting from ionization of the air through which the burning body has passed.

When a rare daylight meteor bursts into view fix its position as accurately as possible in relation to near-by houses, poles or trees and mark the spot at which you are standing. Then measure the path later in altitude and azimuth using a quadrant or protractor and note any other details. Such records will help in fixing the path of the meteor in the air.

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perhaps, in space. Don't forget to include time, direction, and an estimate of brightness, as usual.

The American Meteor Society with headquarters at the Lick Observatory Upper Darby Pa., supplies maps and lists to interested observers, and will in addition offer more detailed information upon request. Completed observations may be sent to the society where they will be studied carefully. For English observers, the meteor-observing section of the British Astronomical Association (London) takes meteor reports.

Since meteors which actually reach the surface of the earth are the only celestial objects we can touch and analyze in person, they are important. They show elements similar to those of the earth and furnish clues to the condition of outer space. In other words, they are well worth finding.

So looking for meteorites is actually another field of observation—one that requires one's every-day powers of observation, rather than the watching of the heavens. Frequently persons find unusual pieces of stone which they take to be meteorites and excitedly proclaim as such. Be cautious and examine the object for certain characteristics before rushing to the laboratory—which is the only place where a final decision may be made.

The first consideration should be to compare it with the rocks of the region. Often the supposed meteorite can be immediately eliminated on this basis. Iron meteorites, because of their unusual weight, instantly distinguish themselves. I don't be fooled by a piece of slag or waste iron. Meteorites are deceptive because some are predominantly iron while others are largely stone, and a third type combines the two materials. Because the iron ones are easier to recognize they are most frequently found. But a bolide, exploding with a loud detonation, is apt to scatter dozens of stone fragments over a small area.

Meteorites usually have a coating on the surface which results from melting as they pass through the atmosphere. This coating, which is extremely thin, has the appearance of black crust or varnish, and is sometimes dull or grayish in color. The surfaces of most meteorites, moreover show ridges or pits that result from unequal melting of the surface in that same passage through the air. Those cavities on the front (as the meteor traveled) are small and deep while those on the rear are broad and shallow. Eventually the weathering effects of rain and wind cause the pits to become deeper and the crust to disappear with the formation of a brown oxide, or rust.

Often meteorites are found on the surface of the ground,

Date	Meteor stream	Rad. R.A.
Jan. 1-4	Quadrantids — <sup>h</sup>	h m
Jan.		15
Feb.		19
Mar.		5 C
Apr.		14 32
May 8	May Aquarids [ Hercalids Pegazids Scorpiids Pons-Winnecke — meteors	18 4
May 11-24		22 16
May 30		16 28
June 2-17		22 0
June 27-30		16 43
July		15 12
Aug.		20 36
Sept.		20 16
Oct.		3 12
Nov.		22 36
Dec.		3 8
Aug. 10-10.	Cygnids	19 20
Aug. 21 III	Dracoids	19 24
Aug. 21 31	[ Draconids	17 28
Sept. 7 15	Persids	4 4
Sept. 22	α Aurigids	4 36
Oct. 3	Quadrantids	15 20
Oct. 9	Giacobids	17 40
Oct. 12 23	ε Arietids	2 48
Oct. 18 23	Orionids	6 8
Oct. 31-Nov 6	Taurids	3 40
Nov 14-18	Leonids	10 0
Nov 26-Dec. 4	Andromedids <sup>o</sup>	1 40
Dec. 10-13	Geminids	7 32

Associated with the orbit of Comet 1861 E.

Associated with the orbit of Halley's Comet.

Associated with the orbit of Comet Pons-Winnecke

Associated with the orbit of Comet 1861 V

Begins by July 20.

Associated with the orbit of Comet Giacobini-Zinner 1933 III. Great show

1 1933 and 1946

Continues until Oct. 31

Also called Perseids. Side important meteor stream has been "lost" for years, narrow stream having been diverted by planetary perturbations but the same may appear again.

or only partly buried because they have lost so much of their velocity in passing through the air. But there are, of course, exceptional instances where they have buried themselves deeply in the earth.

### Meteor Showers for the Year

We give herewith a table of the principal meteor display that are known to occur more or less, each year. The leading ones, which are quite dependable are indicated with asterisk before the respective dates. The others are sometimes conspicuous but are quite uncertain, so that the observer may

not see many meteors. According to Prof. C. P. Olivier, president of the American Meteor Society, the lesser  $\gamma$  (unstarred) meteor streams "probably exist, but there are hundreds of minor radiant, some doubtless detectable each year and not perhaps for several more. As a rule, an observer will not get such a radiant unless he observes all night—or at least for several hours. Nevertheless, many meteors in the lesser-known showers have been observed.

Our list of showers is based upon the most important ones much longer lists by the famous English observer W. F. Fleming. The data as given for the nine main showers are up-to-date, having been checked by Prof. Olivier (1945) besides this, the data of the Meteor Observing Section of the Irish Astronomical Association are taken into consideration. The latter society would have as notes three of the starred showers: the Perseid-Wiasecke meteors, the Taurids, and the Andromedids. In looking for the meteors, consider a late night of the days marked, together with the following timing hours.

## 11 The Asteroids

IN A GREAT broad zone between the orbits of Mars and Jupiter and perpetually circling about the sun in giant ellipses there are thousands of diminutive bodies—each a world in itself. These are the asteroids, known also as minor planets.

The asteroids are likely barren worlds, without water, heat or living things. Why no water? If there had been it would have evaporated into space and there can be no atmosphere on these planets, for they are so diminutive that their gravity is far too small to hold it. The smallest asteroids visible are less than a mile through, as in the case of Adonis. Even on Ceres, the largest, a man weighing 175 pounds on the earth would weigh only about 6 pounds! On still smaller ones the force of gravity is so weak that he would weigh a fraction of an ounce and naturally would have considerable difficulty staying on the ground.

The amount of heat and light received from the sun by the asteroids is governed by distance from that source at the moment, and on the average varies between that received by Mars and that by Jupiter. The light and heat are not absorbed by clouds as in the case of Venus and Jupiter, two cloud-covered worlds, and although some heat is received, there is no atmosphere to hold it and keep it from radiating away, so that the temperature must be near the absolute zero of interplanetary space. It is scarcely conceivable that the asteroids can be the abode of any life.

Asteroids are forever beyond the range of the naked eye, with the exception that one of them can just be seen under most favorable conditions and at certain times. Yet it is not difficult to locate a few of them with low telescopic power—even binoculars—and follow them night after night, during an entire apparition or season of visibility. Usually at least one can be seen with field glasses, and as the size of the glass is increased, a greater and greater number become available.

The immense zone containing nearly all these numerous planets of the solar system is a great ring-shaped belt over 340,000,000 miles from the inner to the outer edge of it.



ably smaller than Ceres and Pallas apparently this has surface material lighter in tone than the others. Relatively few astronomers can see Vesta with the naked eye, but it can be done during apparitions when the opposition magnitude is around 6. Juno at times is fainter than magnitude 9 and needs high-power binoculars or a 2 inch telescope. The magnitudes are continually varying, on account of the relation of the asteroid to the sun and to us.

Astronomically the magnitudes are important first, to designate the brightness as seen by us and thus what telescope aperture is needed. Second they are a basis for determination of size of the minor planet. All but the largest are too small for direct measurement in the telescope. So a mean reflecting power of surface is assumed, which may or may not be true, but which gives a working basis on which to proceed. Then from a knowledge of the orbit and the apparent brightness at opposition, the approximate diameter is computed.

Actually there is an immense and unknown number of minor planets. The greatest number of known ones occurs at magnitudes 13 and 14 of which there are about 400, this number decreasing toward the brighter and toward the fainter side. There are about 1600 asteroids whose orbital elements are sufficiently well known that positions in right ascension and declination are computed for each opposition by various institutions assigned by the International Astronomical Union. These 1600 minor planets might be called the well-known asteroids. Besides these it is estimated that 5000 have been observed at one time or other many of which have been lost or have gone adrift, so to speak, as insufficient observations were secured at the time of appearance for a good set of data to be made, even by the best computers. Leuschner estimates there must be a total of some 50 000 of these spheroids in existence. The vast majority are probably but a mile (more or less) in diameter.

Most of the features of asteroids are of special interest to workers in mathematical astronomy because they concern orbital characteristics. Because we do not know much about the physical nature of the tiny bodies our knowledge is mostly confined to their motions, and to what possible significance they may have in the evolution of the solar system.

The orbits as a whole are much less uniform than those of major planets. The asteroid 944 Hidalgo has a very exceptional orbit. Eccentricity is a numerical relation defining the shape of an ellipse. The nearer it approaches 1.00 the more elongated is the ellipse and the more it departs from a circular form (whose eccentricity is zero). Its orbit

eccentricity of 0.66, which is a very high value, mak-  
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 planets.

Inclination is another of the important qualities of an orbit;  
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 casional obscuration, they rush across the sky at such critical  
 moments with prodigious velocity, rapidly changing position while  
 under observation, with the result that they are discovered  
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Just as the Hermes approached so close to the earth  
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 picked up photographically by German astronomers who  
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Vesta is the minor planet superb, for it is the brightest and  
 is easily observed. Moreover the ephemeris is the most  
 accurate of all and our knowledge of the orbit has been  
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Most of the feature of interest to the professional interest to workers in mathematics is their orbital character. But we would like much about the physical nature of these bodies. Our knowledge is mostly confined to their motion and to what possible significance they may have in the evolution of the solar system.

The orbits as a whole are much like those of the major planets. The semi-major axis is usually between 2 and 4 A.U. The eccentricity is usually small, defining the shape of an ellipse. The nearer it approaches 1, the more elongated is the ellipse and the more it departs from a circular form (whose eccentricity is zero). *Hidalgo's orbit*

catalog. So you must invariably make a prediction, a process which is mathematical. Now that you are at the telescope and find you a chart before you. If observing, you are commonly (the instrument on dates lying between the ones marked in chart, as the probabilities are against your starting at just the day and hour of the marked positions. Obviously position where the asteroid should be at the moment of friction is somewhere along the apparent path or smooth drawn, the exact place being easily estimated according to the date and hour of observing. After having marked selected position by interpolating along the path, you ready to observe.

The telescope ideally would be in a really dark place open to contemplation containing the asteroid. Hold the chart to the telescope (using as dim a light as possible) and tilt that the north-south line on the chart is parallel to the circle of the field of view (this is important) and fixed—dark is, with the "north" of the chart toward the celestial pole, not the north point of the horizon. Then a few moments of being in darkness, you can see the configurations just as they are on the chart. (We assume it is in a very telescope.)

Now find the brightest star of the region near the planet and gradually move the field of view to the planet, labeling all the stars by their configurations and relative positions as on the diagram. The asteroid should be found in proper place, according to the date of observation with to the chart marked on the chart. With practice and sky conditions identifications can often be made to a nicety. At times they have even been made instantly.

If one has picked up the asteroid a day or so before it is familiar with the star groups, or if the asteroid's place is a bright star. The planet will, then, be an extra point distinct from all the other points that are real stars. Moreover by this method you can identify the asteroid with confidence without having to wait a few hours for onset of the object to take place against the starry back-

1  
 If the stationary points in their apparent paths, just as they are reversing direction, a movement from one to the next is apparent. When the object passes close to a (as seen from the earth) movement can be detected in your's time, more or less, depending upon circumstances position and other factors.

As followed by means of the above method in the sphere's and sky conditions.

sunrise. Then with the progress of the season, it can be  
rising earlier and earlier each day until opposition time,  
it is at the observer's meridian at midnight. At this  
it is retrograding. Its appearance continues like that of  
other outer planet in this way that it rises earlier each  
night until finally it is seen in the western sky after  
sundown and gradually becomes lost near the next conjunction  
with the sun in its eastward apparent motion among the stars  
it takes it inaugurating a new cycle. The same routine ha  
to all superior planet.

In observing, one starts with an ephemeris of the star. This is a table of exact positions of the object for regular intervals of time, and the positions are given in coordinates of right ascension and declination. Professional ephemerides are published annually by the Cincinnati Observatory, correspond to the ephemerides of planets as published in *American Ephemeris and Nautical Almanac* of the Naval Observatory, the *Nautical Almanac* (London), others. These positions are also given for the first four planets in the yearly *Handbook of the British Astronomical Association*. There are also a very few monthly periodicals such as *Popular Astronomy*—in which the positions are listed for the asteroid nearest to see during the period covered.

Halt the stir work of picking up an ad rod (and  
 fairly a comet) is it plating it across from the ephe  
 position. The simplest method to plot the apparent co  
 or else use a chart already made. A chart can be made &  
 will cover one or several months course & that usually  
 further hard work. The key for this particular appan  
 of the hyper extending from the true opposition of  
 planet to the sun and the position of the planet

The position of the celestial equator at any one time can be plotted on a chart if the observer's latitude is known. Any star atlas fixed according to the epoch will show the positions of the stars according to their right ascension and declination. The positions of the stars cannot change from year to year. While change from year to year is negligible, it may be taken into account for a number of years. The stars are numbered and lettered for reference and atlases have the names of the stars written in groups placed to correspond with equatorial longitudes.

there breaking the light into various colors. The primary  
 is due to light that enters the upper part of the drops and  
 after one internal reflection, so this bow is always brighter  
 than the secondary bow which undergoes more reflections.  
 All rainbows are caused by sunlight and are seen in the  
 sky, but occasionally the observer is rewarded by a glimpse  
 of a moonbow. So rare are these that sometimes one can  
 see his eyes.

There are sometimes halos around the sun and moon. They  
 have a radius of  $22^{\circ}$  but sometimes  $46^{\circ}$ . They are con-  
 sidered soft white circles in the sky caused by reflection of sun-  
 light or moonlight from ice crystals high up in the atmosphere.  
 The moon halos are similar to the sun halos which are  
 usually produced in the daytime sky. There are many varia-  
 tions, however, and although the moon halos seldom have  
 color the solar phenomena are sometimes vivid circles  
 of color with red on the inside and bluish white on the out-  
 side. When other circlets form on the circumference of the  
 main circle, a comparatively rare occurrence, they are  
 known as mock suns or sun-dogs. The colorless halos are  
 caused by reflection from the surface of ice crystals high in  
 the atmosphere, and the colored ones are produced by pris-  
 tic refraction through the same crystals.

Travelers to the north and south are often puzzled by the  
 length of twilight in these different locations. Explorers in  
 arctic regions report that night follows day very swiftly  
 but visitors to the arctic regions observe that the period  
 of twilight is prolonged through several months. Astronomi-  
 cally twilight is defined as ending at any point upon the  
 earth's surface when the sun is  $18^{\circ}$  below the horizon. The  
 time it takes to get there varies with the latitude and the  
 year. In the middle latitudes twilight usually lasts, and  
 too for that matter  $1\frac{1}{2}$  to  $2\frac{1}{4}$  hours; in higher latitudes  
 longer. The vital factors controlling this variation are  
 the position of the sun. At the equator the varia-  
 tion of the time of the year to another is not  
 more than  $44$  minutes. At  $44^{\circ}$  N. the twilight or dawn may  
 last  $2\frac{1}{2}$  hours in October or March.  
 Dust in the air is responsible for  
 these reflect light from the sun  
 (haze) filling the sky with sun-  
 light. These same dust particles,  
 if they lie between the ob-  
 server and the blue end  
 of the spectrum, will  
 scatter the blue end  
 of the spectrum low in the sky to



phenomena. At times of great auroral displays, the tremendous disturbances in the earth's magnetic field, known as magnetic storms. Magnetic compasses vary several degrees in an hour. At times, too, radio reception, especially short-wave, is affected and sometimes completely cut off. Long-distance telephone cables are also disturbed because of this electric magnetic excitation.

A wealth of folk lore has grown up in the various countries where the aurora is best seen and consistently looked upon. In this have been the stories of sound at time of the aurora. It is likened to the swish of a silk dress, or the wind whistling in a ship's rigging. At present the problem is perplexing, because equally reliable witnesses have given conflicting reports as to any audible phenomenon. Probably the best suggestion is that the supposed effect emanates from a "local brush discharge" of electricity from bushes or snow in the vicinity, similar to the electric discharge from the mast of a ship.

Rainbows are almost as well known as the sun and the moon and are frequently seen in the wake of a rainstorm. They come when the sun peeps through rain clouds, and can be seen too as the sun strikes the spray from a lawn sprinkler or wisps of a fog. Such a display may be seen in the west after a morning shower or in the east after a downpour in the late afternoon. Since rainbows in the popular mind are most commonly associated with summer afternoon storms, they are usually looked for in the east. A rainbow is a group of circular or nearly circular arcs of color that appears as a huge arch in the heavens. No two persons, though they may be standing side by side, ever see the same rainbow for the rainbow is an arc of a circle whose center is on the line stretching from the sun to the eye of the observer.

The ordinary rainbow is an arch of various colors with red on the outside merging into orange yellow green blue indigo and violet. Usually the radius of the arc is equal to about one-fourth of the visible sky or 4 degrees to the red. Once in a while there are two rainbows—the secondary with a greater radius than the first and the order of the colors reversed. Usually the secondary bow is fainter and disappears more quickly than the primary. Observers note that the space between the inner and outer bows is apparently darker than the sky entirely within the arc of the rainbow or the arc entirely outside its sphere of influence. In addition careful watchers observe that the arcs themselves vary in width and that the colors even in the same bow are of variable purity.

Rainbows result from the refraction and reflection of sunlight by raindrops in the atmosphere. Each drop is a prism

...breaking the light into various colors. The primary bow is the light that enters the upper part of the drops and ... after one internal reflection, so this bow is always brighter than the secondary bow which undergoes more reflections. ... are caused by sunlight and are seen in the ... occasionally the observer is rewarded by a glimpse ... So rare are these that sometimes one can ... before his eyes.

There are sometimes halos around the sun and moon; they ... have a radius of 22° but sometimes 46°. They are caused ... ice crystals in the air ... caused by reflection of sun- ... or moonlight from ice crystals high up in the atmosphere. ... moon halos are similar to the sun halos which are ... Early produced in the daytime sky. There are many vari- ... however, and although the moon halos seldom have ... color the solar phenomena are sometimes vivid circles ... color with red on the inside and bluish white on the out- ... When other circles form on the circumference of the ... circle, a comparatively rare occurrence, they are ... as mock suns or sun-dogs. The colorless halos are ... by reflection from the surface of ice crystals high in ... atmosphere, and the colored ones are produced by pri- ... refraction through the same crystals.

Twilight in the north and south is often puzzled by the ... of twilight in these different locations. Explorers in ... regions report that night follows day very swiftly ... like visitors to the arctic regions observe that the period ... twilight is prolonged through several months. Astronomi- ... twilight is defined as ending at any point upon the ... surface ... when the sun is 18° below the horizon. The ... it takes to get there varies with the latitude and time ... year. In the middle latitudes twilight usually lasts, and ... too for that matter, 1½ to ½ hours; in higher latitudes ... longer. The ... factors controlling this variation are ... and declination of the sun. At the equator the varia- ... of twilight from one time of the year to another is not ... over 6 minutes. At latitude 44° N. the twilight or dawn may ... 49 minutes longer on June 1 than on October or March. ... The existence of dust particles in the air is responsible for ... twilight and dawn effect. These reflect light from the sun ... after it has set (and before it rises) filling the sky with ... light even when the sun is invisible. These coarse dust particles, ... floating at the horizon where more air lies between the ob- ... server and the stellar object, absorb much of the blue end ... of the spectrum and therefore turn objects low in the sky to ... a redd-

phenomena. At times of great auroral displays, there are tremendous disturbances in the earth's magnetic field, known as magnetic storms. Magnetic compasses vary several degrees an hour. At times, too, radio reception, especially short-wave, is affected and sometimes completely cut off. Long-distance telephone cables are also disturbed because of this electromagnetic excitation.

A wealth of folk lore has grown up in the various countries where the aurora is best seen and consistently in this have been the stories of sound at time of the aurora. It is likened to the swish of a silk dress, or the wind whistling in a ship's rigging. At present the problem is perplexing. No cause equally reliable witnesses have given conflicting reports as to any audible phenomenon. Probably the best suggestion is that the supposed effect emanates from a "local brush" or discharge of electricity from bushes or snow in the vicinity, similar to the electric discharge from the mast of a ship.

Rainbows are almost as well known as the sun and moon and are frequently seen in the wake of a rainstorm. They come when the sun peeps through rain clouds, and can be seen too as the sun strikes the spray from a lawn sprinkler or wisps of a fog. Such a display may be seen in the wake after a morning shower or in the east after a downpour in the late afternoon. Since rainbows in the popular mind are most commonly associated with summer afternoon storms, they are usually looked for in the east. A rainbow is a group of circular or nearly circular arcs of color that appears as a huge arch in the heavens. No two persons, though they be standing side by side, ever see the same rainbow for each bow is an arc of a circle whose center is on the line stretching from the sun to the eye of the observer.

The ordinary rainbow is an arch of various colors with red on the outside merging into orange, yellow, green, blue, indigo, and violet. Usually the radius of the arc is equal to about one-fourth of the visible sky or 42° to the red. Occasionally in a while there are two rainbows—the secondary with a greater radius than the first and the order of the colors reversed. Usually the secondary bow is fainter and disappears more quickly than the primary. Observers note that the space between the inner and outer bows is apparently darker than the sky entirely within the arc of the rainbow or the arc entirely outside its sphere of influence. In addition, careful watchers observe that the arcs themselves vary in width and that the colors even in the same bow are of variable purity.

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light breaking the light into various colors. The primary bow is due to light that enters the upper part of the drops and is also not internal reflection, so this bow is always brighter than the secondary bow which undergoes more reflections. The colors are caused by sunlight and are seen in the best occasionally the observer is rewarded by a glaucous rainbow. So rare are these that sometimes one can see before his eyes.

There are sometimes halos around the sun and moon; they are like a radius of  $22^\circ$  but sometimes  $46^\circ$ . They are commonly white circles in the sky caused by reflection of sunlight or moonlight from ice crystals high up in the atmosphere. The moon halos are similar to the sun halos which are rarely produced in the daytime sky. There are many varieties, however, and although the moon halos seldom have color the other phenomena are sometimes vivid circles of color with red on the inside and bluish white on the outside. When other circles form on the circumference of the primary circle, a comparatively rare occurrence, they are seen as rock stars or sun-dogs. The colorless halos are caused by reflection from the surface of ice crystals high in the atmosphere, and the colored ones are produced by prismatic refraction through the same crystals.

Travelers to the north and south are often puzzled by the length of twilight in these different locations. Explorers in arctic regions report that night follows day very swiftly. The visitors to the arctic regions observe that the period of twilight is prolonged through several months. Astronomically twilight is defined as ending at any point upon the earth's surface when the sun is  $18^\circ$  below the horizon. The time it takes to get there varies with the latitude and time of year. In the middle latitudes twilight usually lasts, and even too for that matter  $1\frac{1}{2}$  to  $2\frac{1}{2}$  hours; in higher latitudes even longer. The chief factors controlling this variation are latitude and declination of the sun. At the equator the variation of twilight from one time of the year to another is not more than 6 minutes. At latitude  $44^\circ$  N. the twilight or dawn may be 49 minutes longer on June 1 than in October or March. The existence of dust particles in the air is responsible for the twilight and dawn effect. These reflect light from the sun after it has set (and before it rises) filling the sky with sunlight even when the sun is invisible. These same dust particles, however, at the horizon where more air lies between the observer and the stellar object, absorb much of the blue end of the spectrum and therefore turn objects low in the sky to a reddish

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[illegible]

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Thus, if you studied the heavens well, you need only go toward a star that you knew to be directly above the place that was your destination and you would be guided to it. Furthermore, you could even judge how near to your destination you were getting, because as you approached it that star would come nearer and nearer to your own zenith. The principle would be the same if you were to see a light atop a tall building. By walking toward that light, you would approach the building and as you approached, the light would seem to climb higher and higher in the skies.

In actual practice of course it was not quite as simple that. The Polynesian navigator to earn his laurels, had to be familiar with all the stars which passed over the islands which he sailed, so that as one moved on and ceased to be near his destination, he could select another to take its place. Since he followed this heavenly guidance without instruments, it was only approximate. He had to be able to read the signs of the seas as well so that he could tell by the birds and the clouds, by odors and by countless other small indications when he was nearing a landfall.

But the system worked well enough to support a flourishing traffic between the islands and win great fame for the master who guided the ships. Today when an incomparably finer system of navigation exists, so that ships and planes are guided at their geographic targets with pin-point accuracy the navigator still falls heir to some of the awe with which the natives beheld him.

And this despite the fact that the actual practice of modern navigation has been stripped of practically all its trigonometrical and astronomical mystery and reduced to the point where with proper instruction and considerable care, almost any intelligent person can find his way by the stars. More than one sailor has learned the tricks of his trade from the books in the New York Public Library—and one Robinson circumnavigated the globe in a small sailing vessel armed only with the knowledge gained in such a fashion.

Today thanks to the U. S. Naval Observatory, the Hydrographic Office and other government agencies, there exist a few brief volumes that, taken together solve all the perplexing riddles of navigation, leaving the sailor little more to do than make observations and look up the answers in the published tables. The task is much easier than that which confronted the Polynesian master for all the trigonometric and astronomical computations have been worked out in advance and simple arithmetic can take care of the remainder.

position is not, of course, so ridiculously easy that you can do it by reading one brief chapter in a book devoted to other aspects of astronomy nor would any student venture forth on the high seas without giving extensive practice in making observations with the aid of performing the other routine tasks involved. The equations, simple though they may be in theory and practice, call for a high degree of accuracy and, consequently, with the result that the navigator might be disappointed as a reward for carelessness. In using the sextant, an instrument with which the angular distances of the sun and stars are determined, practice is essential. You can hardly hit the bull's-eye without constant practice. The principles involved in following the pathway of a star can be grasped without undue difficulty and, once understood, the reason for each step in navigation and the importance of painfully careful observations become clear. One of the things to be recalled at the start is that the modern navigator no longer thinks of directions in such terms as "north-east" or "south by south-west." He measures clockwise around the horizon from the north being both  $0^\circ$  and  $360^\circ$  east being, on the compass,  $90^\circ$  south,  $180^\circ$  and west,  $270^\circ$ . It is possible for him to indicate direction accurately simply—when bearing is given as  $35^\circ$  there is no question as to how far north of northeast it is. He merely marks around the horizon from the north point and proceeds in direction, assuming, of course, that he possesses a reliable compass with which to make the measurements. There are, naturally other and simpler methods of navigation that which depends upon observations of the stars and heavenly bodies. But they are inadequate for transoceanic and serve as supplements to celestial navigation and as substitutes. Under limited circumstances, they stand on their own. Piloting, for example is nothing more than finding one's way by reference to known landmarks—the boatman uses it in familiar waters, the airplane pilot while flying in short hops over well-mapped country. Once out of sight of land, however, the aviator too finds it of little aid. Dead-reckoning is more important, and, when for various reasons it is impossible to refer to the heavenly bodies, both in fact and in for extended periods. Moreover, modern dead-reckoning with radio signals—



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Thus, if you studied the heavens well, you need only set sail toward a star that you knew to be directly above the island that was your destination and you would be guided to it. Furthermore you could even judge how near to your destination you were getting, because as you approached it that star would come nearer and nearer to your own zenith. The principle would be the same if you were to see a light atop a tall building. By walking toward that light, you would approach the building and as you approached the light would seem to climb higher and higher in the skies.

In actual practice, of course, it was not quite as simple that. The Polynesian navigator to earn his laurels, had to be familiar with *all* the stars which passed over the islands which he sailed so that, as one moved on and ceased to mark his destination, he could select another to take its place. And since he followed this heavenly guidance without instrument it was only approximate. He had to be able to read the sign of the seas as well so that he could tell by the birds and fish, by clouds, by odors, and by countless other small indications when he was nearing a landfall.

But the system worked well enough to support a flourishing traffic between the islands and win great fame for the man who guided the ships. Today when an incomparably finer system of navigation exists, so that ships and planes are able to strike at their geographic targets with pin point accuracy the navigator still falls heir to some of the awe with which the ancient beheld him.

And this despite the fact that the actual practice of modern navigation has been stripped of practically all its trigonometrical and astronomical mystery and reduced to the point where with proper instruction and considerable care almost any intelligent person can find his way by the stars. More than a sailor has learned the tricks of his trade from the books in the New York Public Library—and one Robinson circumnavigated the globe in a small sailing vessel armed only with the knowledge gained in such a fashion.

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Navigation is not, of course, so ridiculously easy that you learn the art by reading one brief chapter in a book devoted to numerous other aspects of astronomy nor would any able student venture forth on the high seas without giving himself extensive practice in making observations with the sextant and performing the other routine tasks involved.

These operations, simple though they may be in theory and practice, call for a high degree of accuracy and, consequently for a well-developed skill. The slightest error may be greatly magnified, with the result that the navigator might be disappointed as a reward for carelessness. In using the sextant, an instrument with which the angular distances of moon, and stars are determined, practice is essential. You discharge a rifle by squeezing the trigger but few people consistently hit the bull's-eye without constant practice.

However, the principles involved in following the pathway the stars can be grasped without undue difficulty and, once they are understood, the reason for each step in navigation and importance of painfully careful observations become clear.

One of the things to be recalled at the start is that the modern mariner no longer thinks of directions in such terms as "north-northeast" or "south by southwest." He measures distances in degrees clockwise around the horizon from the north point, north being both  $0^\circ$  and  $360^\circ$ , east being, on the same compass,  $90^\circ$ , south,  $180^\circ$  and west,  $270^\circ$ .

Thus it is possible for him to indicate direction accurately and simply—when bearing is given as 35 there is no question as to how far north of northeast it is. He merely marks it around the horizon from the north point and proceeds in that direction, assuming, of course, that he possesses a reliable compass with which to make the measurements.

There are, naturally, other and simpler methods of navigation than that which depends upon observations of the stars and heavenly bodies. But they are inadequate for transoceanic travel and serve as supplements to celestial navigation rather than as substitutes. Under limited circumstances, they may stand on their own.

Piloting, for example, is nothing more than finding one's way by reference to known landmarks—the boatman uses his familiar waters, the airplane pilot while flying in short hops over well-mapped country. Once out of sight of land, however, both of small use to the mariner and high in the stratosphere the aviator too finds it of little aid.

Dead-reckoning is more important, and, when for various reasons it is impossible to refer to the heavenly bodies, both pilot and ship fall back on it for extended periods. Moreover, the latter can supplement dead-reckoning with radio signals—

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THE ART OF NAVIGATION

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Thus, if you studied the heavens well, you need only set out toward a star that you knew to be directly above the island that was your destination and you would be guided in it. Furthermore you could even judge how near to your destination you were getting, because as you approached it that star would come nearer and nearer to your own zenith. The principle would be the same if you were to see a light atop a tall building. By walking toward that light, you would approach the building and as you approached the light would seem to climb higher and higher in the skies.

In actual practice, of course, it was not quite as simple as that. The Polynesian navigator to earn his laurels, had to be familiar with *all* the stars which passed over the islands which he sailed, so that, as one moved on and ceased to mark his destination, he could select another to take its place. As since he followed this heavenly guidance without instruments it was only approximate. He had to be able to read the signs of the seas as well so that he could tell by the birds and by clouds, by odors and by countless other small indications when he was nearing a landfall.

But the system worked well enough to support a flourishing traffic between the islands and win great fame for the masters who guided the ships. Today when an incomparably finer system of navigation exists, so that ships and planes are aimed at their geographic targets with pin-point accuracy the navigator still falls heir to some of the awe with which the ancients beheld him.

And this despite the fact that the actual practice of navigation has been stripped of practically all its trigonometrical and astronomical mystery and reduced to the point where, with proper instruction and considerable care almost any intelligent person can find his way by the stars. More than one sailor has learned the tricks of his trade from the books in the New York Public Library—and one Robinson circumnavigated the globe in a small sailing vessel armed only with the knowledge gained in such a fashion.

Today thanks to the U. S. Naval Observatory, the Hydrographic Office, and other government agencies, there exist a few brief volumes that, taken together solve all the perplexing riddles of navigation, leaving the sailor little more to do than make observations and look up the answers in the published tables. The task is much easier than that which confronted the Polynesian master for all the trigonometric and astronomical computations have been worked out in advance, and simple arithmetic can take care of the remainder.

Navigation is not, of course, so ridiculously easy that you learn the art by reading one brief chapter in a book devoted to numerous other aspects of astronomy, nor would any able student venture forth on the high seas without giving himself extensive practice in making observations with the sextant and performing the other routine tasks involved. These operations, simple though they may be in theory and practice, call for a high degree of accuracy and, consequently for a well-developed skill. The slightest error may be amplified, with the result that the navigator might be as disastrous as a coward for carelessness. In using the sextant, an instrument which has the angular dimensions of an inch, and which are determined by practice is essential. You discharge the instrument by squeezing the trigger but few people consistently hit the bull's-eye without constant practice. However the principles involved in following the pathway of a star can be explained without undue difficulty and, once understood, the reason for each step in the process and the proper point in the sky will become clear. One of the things to be recalled at the start is that the modern navigator never thinks of direction in such terms as north, south, east, or west. He measures direction around the horizon from the north point, and the east being on the horizon is 90 degrees and west is 270 degrees. He measures direction accordingly. There is no question as to the north point and proceeds to the point where he possesses a reliable means of direction. The simplest methods of navigation are the observations of the stars. The observations are inadequate for transits to celestial navigation in limited circumstances, they are not more than finding one's landmarks—the navigator uses the pilot's rule flying to short hops. One can get of land, however, and high in the atmosphere. It is not important and, when for various reasons, the pilot is only bodies, both for extended periods. Moreover, reflecting with radio signals—

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Plotting, for example is nothing more than finding one's way by reference to known landmarks—the boatman goes to familiar waters the airplane pilot while flying in short hops over a mapped country. Once out of sight of land, however, of small use the mariner and high in the stratosphere navigator for much of little aid.

Dead-reckoning is more important, and, when for various reasons it is impossible to refer to the heavenly bodies, both at sea and far off land on for extended periods. Moreover, it can supplement dead-reckoning with radio signals—



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And thus despite the fact that the actual practice of modern navigation has been stripped of practically all its trigonometrical and astronomical mystery and reduced to the point where with proper instruction and considerable care almost any intelligent person can find his way by the stars. More than one sailor has learned the tricks of his trade from the books in the New York Public Library—and one Robinson circumnavigated the globe in a small sailing vessel armed only with the knowledge gained in such a fashion.

Today thanks to the U. S. Naval Observatory, the Hydrographic Office and other government agencies there exist few brief volumes that taken together solve all the perplexing riddles of navigation, leaving the sailor little more to do than make observations and look up the answers in the published tables. The task is much easier than that which confronted the Polynesian master for all the trigonometrical and astronomical computations have been worked out and reduced to simple arithmetic.

Navigation is not, of course, so ridiculously easy that you learn the art by reading one brief chapter in a book devoted to numerous other aspects of astronomy nor would any able student venture forth on the high seas without giving self extensive practice in making observations with the sext and performing the other routine tasks involved.

For a high degree of accuracy and, consequently, for a well-developed skill. The slightest error may be magnified, with the result that the navigator might find his destination as a reward for carelessness. In using the sext, an instrument with which the angular distances of the moon and stars are determined, practice is essential. You discharge a rifle by squeezing the trigger but few people consistently hit the bull's-eye without constant practice.

However the principles involved in following the pathway of stars can be grasped without undue difficulty, and, once understood, the reason for each step in navigation and importance of painfully careful observations become clear.

One of the things to be recalled at the start is that the modern mariner no longer thinks of directions in such terms as north-northeast or south by southwest. He measures distances in degrees clockwise around the horizon from the north point, north being both  $0^\circ$  and  $360^\circ$  east being, on the modern compass,  $90^\circ$  south,  $180^\circ$  and west,  $270^\circ$ .

Then it is possible for him to indicate direction accurately when a bearing is given as 35. There is no question as to how far north of northeast it is. He merely marks around the horizon from the north point and proceeds in the direction, assuming, of course, that he possesses a reliable compass with which to make the measurements.

There are, naturally, other and simpler methods of navigation than that which depends upon observations of the stars—namely, heavenly bodies. But they are inadequate for transoceanic travel and serve as supplements to celestial navigation rather than as substitutes. Under limited circumstances, they stand on their own.

Navigation, for example, is nothing more than finding one's way by reference to known landmarks—the boatman uses it in familiar waters, the airplane pilot while flying in short hops over well-mapped country. Once out of sight of land, however, of small use to the mariner and high in the stratosphere for the aviator, dead reckoning is more important, and, when for various reasons it is impossible to refer to the heavenly bodies, both the mariner and the aviator fall back on it for extended periods. Moreover, the radio can supplement dead reckoning with radio signals—

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Plate VIII Meteor Crater

View from south rim of Meteor Crater, near Canyon Diablo, Arizona. Camera looks north. Main scarps to the depression in the northern horizon look believed to have resulted from the north-south angle of descent of the meteor or small comet that caused the earth-scar. The bottom of the crater about 400 feet below the northern rim is the foreground shows the snow-capped San Francisco peak, highest in range. Photo graph by Hubert J. Bernhard



**Plate XI A S ERIAN "SMOKE RING".** The well known Ring Nebula in Lira Minder's In telescope it appears just like smoke ring! a large instrument the complex structural details visible. It is the 15th magnitude star in the middle.  
(Mt Wilson Observatory)



PLATE VII THE NORTH FACE ARMOUR. A  
the ... ..







1

Plate VI A STELLAR "SMOKE RING" The well known Ring Nebula in Lyra Minder 47. In a telescope it appears just like smoke ring. A large instrument the complex structural details visible as well as the 14th magnitude star in the middle.

(Mt Wilson Observatory)



2



Plate VII THE NORTH STAR ARROW A remarkable appearance in the northern boreal (northern) hemisphere



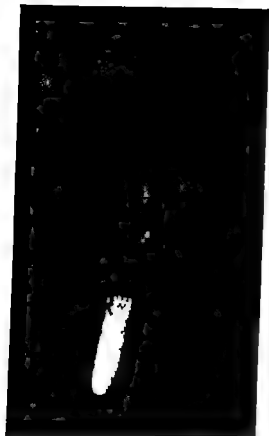


Plate VII **Halley**  
Comet Halley, one  
of the largest of the  
naked eye comets,  
had a proportionally  
large nucleus, as  
shown in this photo-  
graph. Last seen in  
1910, this comet will  
not return to the  
earth again until  
1986 (Photograph  
by Perrier Obser-  
vatorio Astronomico  
Córdoba Argentina.)



Plate VIII **Jupiter** The surface of Jupiter, largest planet in the solar system, is belted by clouds which are characterized by intricate and ever-changing details. Actually, the atmosphere is composed of gaseous gases at extremely low temperatures. (Allison Observatory.)





Plate VII **HALLEY'S COMET** Halley's comet

is the largest of the naked eye comets, had a proportionally large nucleus, as shown in this photograph. Last seen in 1910, this comet will not return to the earth again until 1986. (Photograph by Ferruccio Osservatorio Astronomico Córdoba Argentina)



Plate VIII **JUPITER** The surface of Jupiter, the solar system, is belted by clouds which are characterized by their ever-changing details. Actually, the atmosphere is composed of different gases at extremely low temperatures. (All Halley's Observations)

Late A. Travers's  
 paper. The Great  
 Comet of 1871 dis-  
 covered with the as-  
 sistance of John  
 Lubbock, of New  
 South Wales, an as-  
 tronomer, called ab-  
 out 1871, exhibited  
 a like nucleus,  
 typical coma and  
 brilliant, bearded  
 tail. Found by Travers  
 and Charles Smith.  
 No. 2.



The 11 Parts of Comet are illustrated here in the Great Comet  
 not shown in diagram and photograph. This comet, discovered  
 by Travers, was an extraordinary object, it threw off 11 envelopes.  
 On June 10, 1871, appeared the earth passed through the  
 peculiar atmosphere effect was observed.  
 Photograph. Warren de la Rue & son, Cambridge, for Capt.



Plate VII HALLEY  
(COMET Halley, one  
of the largest of the  
naked eye comets,  
had a proportionally  
large nucleus, as  
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Córdoba 1 gm  
line.)



Plate VIII JUPITER The surface of Jupiter, largest planet in the solar system, is belted by clouds which are characterized by intricate and ever-changing details. Actually the atmosphere is composed of densely gaseous and extremely low temperatures. (Mt. Wilson Observatory.)

1. The Great Comet  
 2. The Great  
 3. Comet of 1811  
 4. discovered with the  
 5. telescope in John  
 6. Robert of New  
 7. South Wales, an as-  
 8. tronomer, comet ob-  
 9. server, who is believed  
 10. to be the author  
 11. of the comet, and  
 12. the comet, believed  
 13. to be the comet in the  
 14. comet (Charles Smith  
 15. or John)



1. 17 Parts of the comet are illustrated here in the Great Comet  
 2. and shown in diagram and photograph. The comet, discovered  
 3. by John, was an extraordinary object in that all 11 envelopes  
 4. 1 days in June 10, as appeared the earth passed through the  
 5. 2 perihelion atmosphere effect are observed  
 6. Photograph. (From the New York Times, 1811)





Plate VII HALLEY'S COMET Halley's, one of the largest of the naked eye comets, had a proportionally large nucleus, as shown in this photograph. Last seen in 1910, this comet will not return to the earth again until 1986 (Photograph by Perito Observatorio Astronómico Córdoba, Argentina)



Plate VIII JUPITER The surface of Jupiter, largest planet in the solar system, is belted by clouds which are characterized by intricate and ever-changing details. Actually the atmosphere is composed of deeply gases at extremely low temperatures (After William O. Walker)





PLATE IV. THE MOON (CONTINUED)

Rugged mountains, stretches of barren plain, deep bays, innumerable crater forms—all the rough hewn features of the lunar surface shown in this picture of the south polar region of the moon from Pitkin's Observatory.

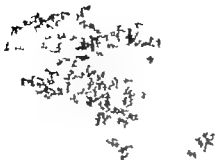


Photo 1 C

1000 1000 low up at 1000. In Southern Cross down along the 10-  
 1000 1000 1000 dark outline on the lower left of the 1000 1000 1000  
 1000 1000 1000 When crossing the meridian the 1000 1000 1000  
 1000 1000 1000 all of the 1000 1000 1000 nearly perpendicular to the horizon  
 1000 1000 1000 up between 1000 1000 1000 (Lunar Observatory 1000-  
 1000 1000 1000 1000



PLATE IV. THE MOON (CONTINUED)

Rugged mountains, stretches of bare plain, deep valleys, and considerable crater forms—all the rough hewn features of the lunar surface are shown in this picture of the south polar region of the moon (from Ptarmigan to the pole (Mt. Wilson Observatory)).



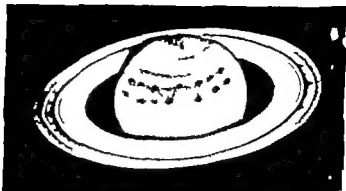


Plate II RINGS PLANET The large planet Saturn in dra-  
 Mare Maggiori at Arcetri Italy. In nearly the mid-  
 opening of the rings as seen from the 17th Division of the  
 rings is apparent and the sub-  
 belt and spotted pattern of the planet the darker polar  
 the irregularities of the shadow of the planet on the rings  
 details in the outer ring are some of the features observed

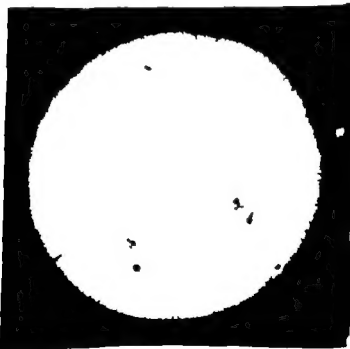


Plate III SUN SPOTS The solar disk as it appeared at the time of  
 the April, 1910 sun spot maximum. The largest spots, which  
 occur in groups, were each large enough to engulf many earths  
 (All from Observatory)

